

The WHAT'S NEW magazine

OCTOBER 1988

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Popular Science®

Hot news
in home heating

Tornadoes—
tracking down
their secrets
to save lives

Low-cost fax

HORSEPOWER!



THE FORD/ CHEVY RACE IS ON

- Wringing more power from production engines
- '89 lineups—world-class cars take on imports
- New light trucks—best performance ever



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**YOU GOTTA BE TOUGH
TO STAY #1.**

TOUGH '89 BIG FORD PICKUP- AMERICA'S BEST-SELLER.

Year after year, Americans have chosen tough Ford pickups over all others.* And they're satisfied with their choice — because Ford has the highest percentage of *repeat* buyers of any full-size pickup!** Last year Ford's F-Series pickups beat Chevy again by a big margin. That's truck leadership! Ford's built aerodynamic, Hi-Tech and tough — and even better for 1989!

BIGGER ENGINE, MORE TORQUE!

Ford's pickups offer a bigger standard

Six — with 10% more torque than Chevy. V-8's range from most powerful small gas V-8 to biggest diesel in *any* pickup. Only Ford pickups offer four multiple-port electronic fuel-injected engines. When properly equipped, some Fords are rated to tow a 12,500-lb. trailer.

COMFORT, CAB CHOICE.

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rear wheels. The interior of all Ford cabs are roomy and comfortable.

BIGGER CARGO BOX, MORE PAYLOAD.

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Buckle up — together we can save lives.

Ford's maximum payload exceeds Chevy's for each series — up to 1,000 lbs.

BIGGER VALUE.

Fords also come with standard equipment the Chevy C/K doesn't. Features like AM radio with digital clock, cigar lighter and four gauge package.

All big Ford pickups have gas-pressurized shocks, standard — optional only on Chevy K1500. Ford was first with rear Anti-lock brakes, aerodynamic styling, and 4x4 Twin Traction Beam independent front suspension.

Now's the time to buy or lease a tough Ford pickup!

SPECIFICATIONS

ENGINES

4.9L EFI Six
145-hp.

5.0L EFI V-8
185-hp.

5.8L EFI V-8
210-hp.

7.5L EFI V-8
230-hp.

7.3L diesel
180-hp.

PAYLOADS

F-Series 4x2
pickups:
1575 to 5270 lbs.

F-Series 4x4
pickups:
1750 to 4295 lbs.

CABS

Regular 3-Man Cab
Ford 2-Door

SuperCab
Ford 4-Door

Crew Cab

MAJOR STANDARD EQUIPMENT

Power brakes
Power steering
5-speed OD
transmission
Gas-pressurized
shocks
Electronic radio
& clock
Full instrumentation

BEST-BUILT AMERICAN TRUCKS 8 YEARS RUNNING.

Based on an average of owner-reported problems in a series of surveys of '81-'88 models designed and built in North America. At Ford, "Quality is Job 1."

*Based on 1988 model year manufacturers' reported retail deliveries through July.

**Based on 1987 New Car And Truck Buyer Study.



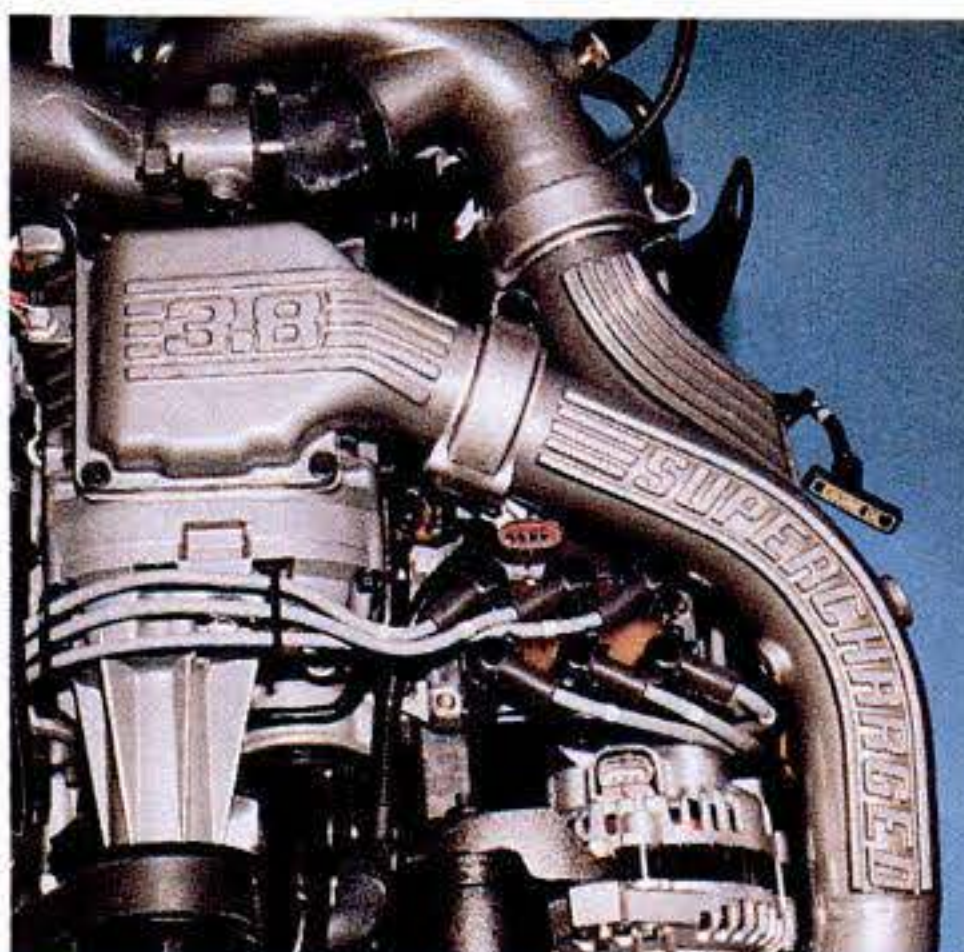
This One



EU4K-64W-LTF2

Horsepower!

Our new-car section covers the power race in Detroit: A blend of the best of European and Japanese engineering has inspired some of Motor City's fastest cars in years—and they don't guzzle gas. Trucks, too, get more muscle. And Detroit's going global: More than ever, your new U.S. car may have a Japanese engine, German transmission, or Italian skin. [Page 17](#)



Jump jet

The Falklands War "hero" has been redesigned: Take a spin in an AV-8B Advanced Harrier II jump jet with a POPULAR SCIENCE editor and learn what it's like to hover like a hummingbird, then [lightly touch down. Page 56](#)



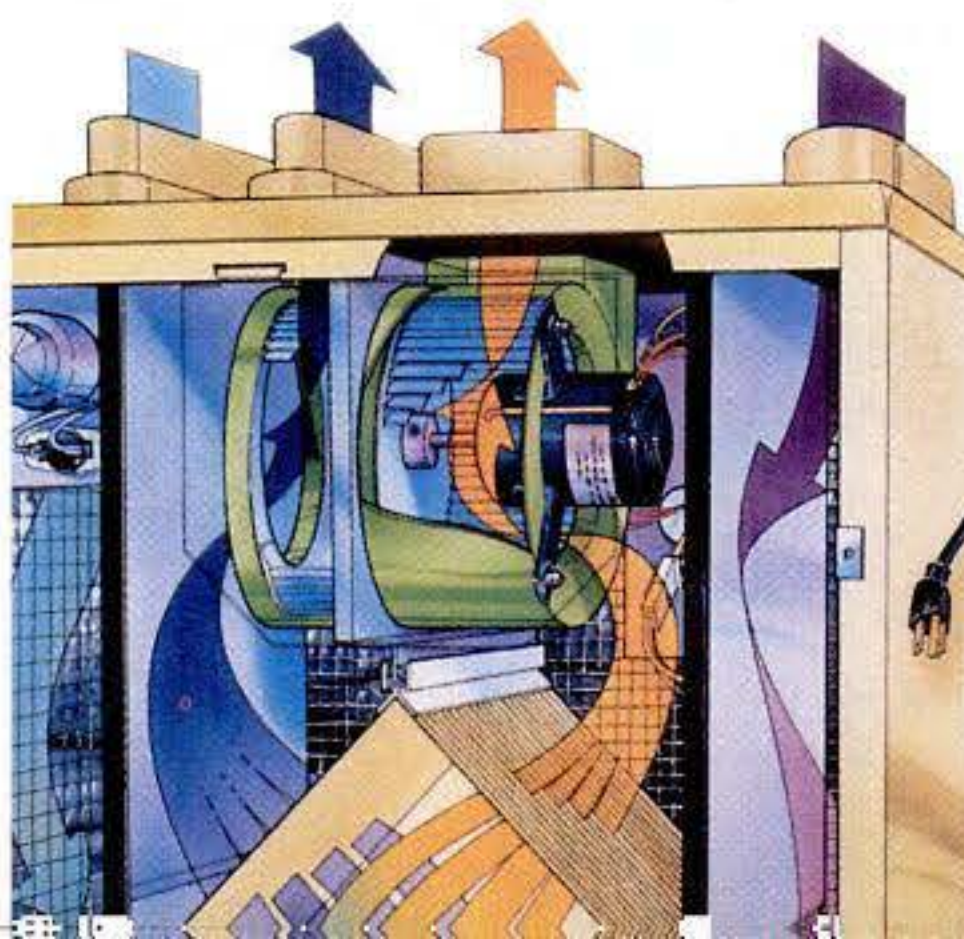
Tornado

Each year about 850 tornadoes hit the dozen or so states called "tornado alley." Our author goes on a tornado chase to see how meteorologists are using portable Doppler radar equipment to learn what happens inside the violent twisters. The new data will improve forecasting and save lives. [Page 65](#)



Hot news in home heating

You can conserve energy without sacrificing comfort and convenience. The stories and new products featured in our special section give you [all the details. Page 79](#)



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COVER ENGINE PHOTOS
BY JOHN B. CARNETT



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Readers Talk Back

Comforts of home

After reading the August car test, "Upward Mobility," I decided that the Lincoln Continental would be my choice because of its roomy interior. All it lacks is a Porta-John portable toilet, but with a 19-plus-cubic-foot trunk I'd have one installed. Should I sell my house?

Robert G. Nylander
Greenfield, Mass.

Double-decker Lincoln

I eagerly await each issue to peruse your car tests. But I'm really amazed at your "Upward Mobility" recap showing the Continental taller than it is wide. Years ago I spotted a tall black Lincoln limousine in the Ford executive garage especially designed for the Ford family so the ladies could wear hats in comfort. Is this new taller-than-wide Continental in that tradition or have the figures been switched?

A. R. Croci, Spring Hill, Fla.

Sorry, hats off in the new Lincoln—the latter occurred.

Doctor, I'm cured

My three-year-old 900-square-foot redwood deck could easily have been the subject for August's "Deck Doctors." Due to my resistance to covering the natural wood with a stain, the deck had gone through gray to black. I called United Gilsonite Laboratories, and they quickly gave me the name of a direct shipper (Deco Supply, Dodgeville, Wis.) and provided expert advice on application. After only four hours of work my deck is again red and looks like the day it was built, all without damage to nearby plants, lawn, or the human body. Many thanks for the article and to UGL and Deco Supply for their assistance.

Michael D. Watson, Petaluma, Calif.

Wanted: dumb house

As I read "Smart House" [Aug.], it occurred to me that the day of the atomic-powered can opener has finally arrived. I hate to be a spoilsport, but I've lost too many bouts to so-called

"smart" devices that are harder to use than the dumb ones they replace. I'm not sold on the new technology. Besides, there already is a device on the market that ensures an electric light will come on when it's dark and someone enters the room: It's called a wall switch.

Thomas Sales, Somerset, N.J.

Piano men sound off

As a tuner technician and member of the Piano Technicians Guild, I was interested to read in August's "What's News" about the piano strings that won't stretch [Frigid Notes]. However, the amount that the strings stretch is only a small part of why a piano goes out of tune within six months' time. As long as the string bears on a wooden bridge attached to a wooden soundboard, seasonal humidity changes will cause those components to swell and shrink. As the wood changes shape, so change the strings.

David Flanders, Wakefield, R.I.

The antique piano described in Frigid Notes that stayed in tune for 2½ years is not too unusual. As a piano ages, the soundboard will sometimes lose enough of its crown that its bearing on the strings is largely eliminated. This reduces the effects of humidity changes on the soundboard, and the strings stay in tune.

William J. Clayton II
Registered Tuner Technician
Charlotte, N.C.

Real-world TCAS

The August article on the Federal Aviation Agency's collision-avoidance system ["TCAS: Can It Stop Midair Collisions?"] brought out the fact that pilots need electronic help to extend their visibility. However the TCAS test was not representative of the real world. TCAS operates by utilizing the air-traffic control (ATC) transponders as the inter-aircraft data-exchange means. The radar beacon systems are shared with air-traffic controllers, but only on a noninterference basis. Anytime a controller notes a two-percent degradation in his ATC communications brought on by TCAS usage, he can command all TCAS equipment off by radio.

You cited the Los Angeles basin as

Continued

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A close-up photograph of a glass filled with whiskey and several ice cubes. The glass is partially filled with a golden-brown liquid, and the ice cubes are partially submerged, creating a textured surface. The background is dark and out of focus.

Seagram's
V.O.

FIND GOLD TONIGHT.

an example of an area where there might be 25 aircraft within a five-nautical-mile radius. The FAA reports that at Los Angeles International Airport there may be as many as 1,105 aircraft airborne simultaneously. If 20 percent are TCAS-equipped, that's 221 aircraft using the same radar beacon frequencies as the air-traffic controller facilities—five in the LAX area. On the East Coast, there are places where aircraft may be in range of over 30 such ATC stations. In those areas TCAS will never be permitted to be turned on. This means that it is entirely possible for a TCAS-equipped airliner on a short commuter run to make a full flight, including takeoff and landing, without ever once having an operable TCAS. In effect, TCAS will have virtually no value in precisely those areas where its advertised protection is needed the most.

Edmond Gunny, Los Angeles, Calif.

Metamorphic wallboard

Phase-change wallboard ["Wallboard Undergoes a (Phase) Change," Aug.] may have some important uses, especially if flammability and cost can be controlled. But it suffers from a basic limitation: its fixed phase-change temperature. If I choose a phase-change material that melts at 70 degrees F, this is fine for winter. But when the summer arrives and I want to keep rooms at 75 degrees, no freezing or melting will occur (the PCM will always be in the liquid state) and consequently there will be practically no stabilization. Also, suppose I sell my house to a family that likes a 65-degree temperature in winter. The new owner will be out of luck because the PCM is inoperative at these temperatures. My dream would be to find a way to vary the PCM operating range according to season and lifestyle.

William A. Shurcliff
Cambridge, Mass.

Persistent patio paving

July's article "Dry-Laid Paving" reminded me of my two attempts to create a stable, attractive patio for a screen house. In the first attempt I used a procedure almost identical to the one John Robinson suggests in the article. But shortly after completion the blocks began to pop up. Then I learned about soil cement. The Portland Cement Association suggested a mix of 10 percent cement (powder type) with 90 percent sand; stone-free soil can also be used. My second patio has held up for 20 years! My sugges-

tion: Follow the Robinson plan, but use soil cement.

Rod A. Porter, Horseshoe Bend, Ark.

For more information on soil-cement, see this month's article "Dirt-Cheap Dirt Floor."

Steady she goes

I got a little confused by the following statement in "Unshakable Camcorders" [July]: "When the built-in electronics and sensors detect movement in one direction—like up or down from bumps—the motors quickly compensate. Result: a steady picture despite the terrain." What would the camcorder do if you wanted it to move up or down to record fast action? Would the motors still compensate for the wanted movement?

Brian Long, Springfield, Mo.

Yes, they do. And if you pan left and right quickly, the camcorder takes time to catch up with you, resulting in a smooth, slow pan. The lens motors can be turned off to record quick movements.
—William J. Hawkins

Big 'n' oil-less

I would like to call attention to one small error in July's otherwise excellent article "Air Power." Phil McCafferty writes that "Oil-less compressors are generally low-horsepower models only... Piston-type oiled compressors are the only choice for compressors over 1 hp." In actuality, several makers are currently producing oil-less air compressors in 1½-, 2-, and 2½-hp models, as well as in smaller sizes.

John S. Mose

Home Air Compressor Association
Chicago, Ill.

Code violator

Wiring tip number three in the August short "Three Wiring Tips" suggests running a lamp cord through an inside wall to get to a receptacle. This is a violation of the 1987 National Electric Code section 400-8.

Michael T. Fussell, P.E.
Missoula, Mont.

Resistant reader

I found the word "resister" in the Super Key item in August's "Automotive Newsfront." The correct spelling is resistor. I was amazed to find this mistake, but I know it can happen. Thanks for a fine magazine.

K. L. Kunath, Spencer, Iowa

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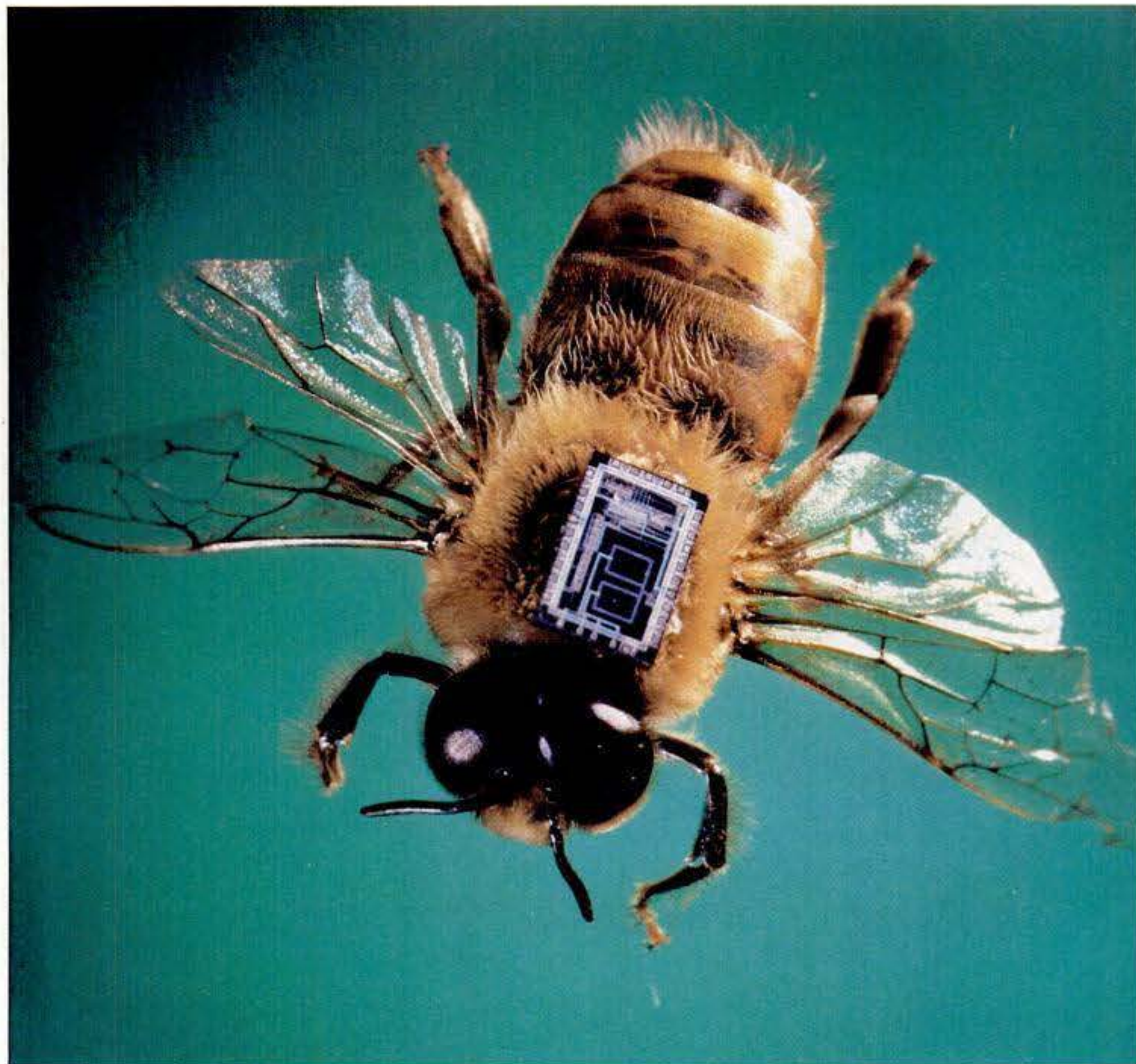
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Science Newsfront

By ARTHUR FISHER



This tiny self-powered chip will be glued to Africanized honeybees to help

A chip on the old bee

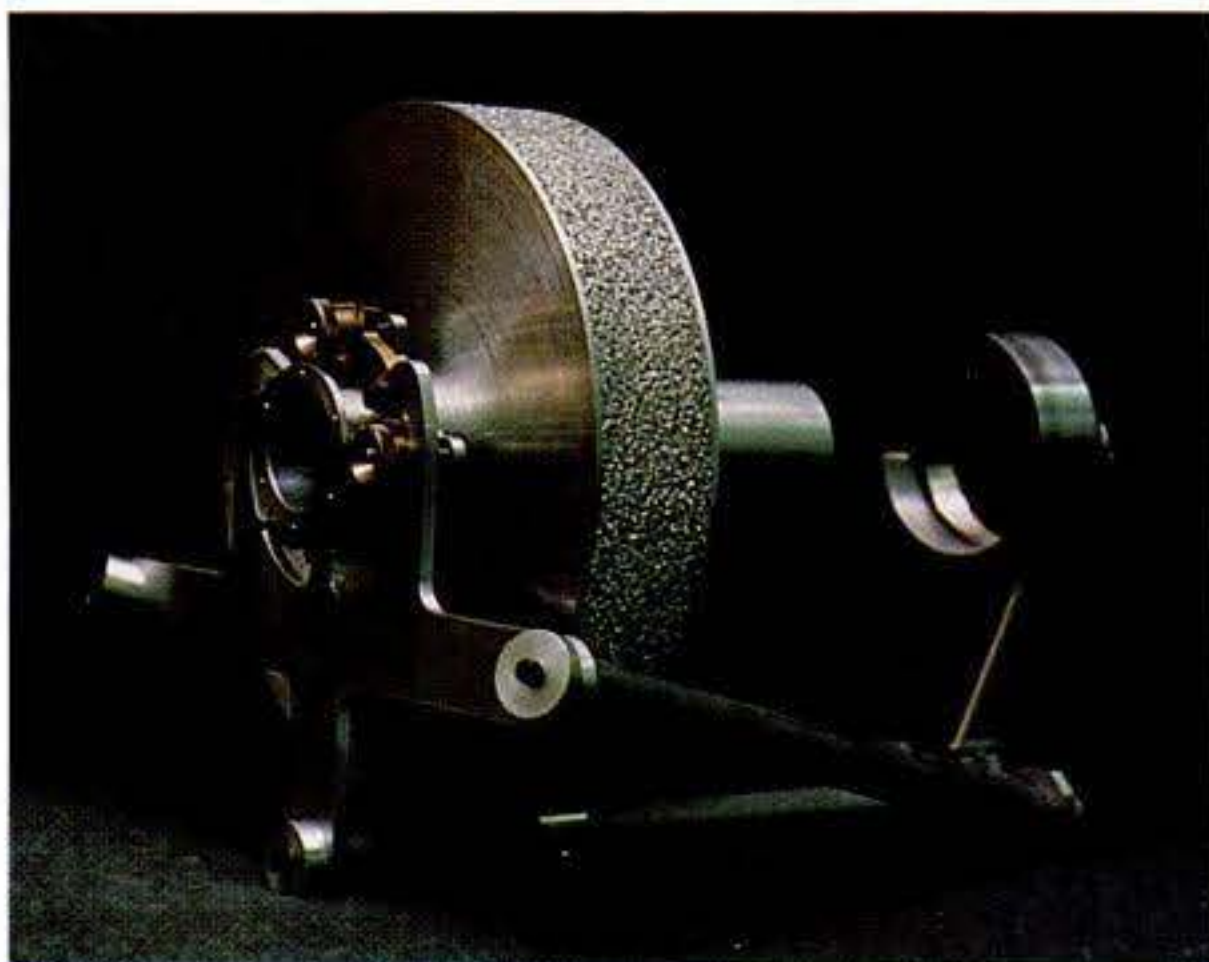
The small chip glued to the thorax of the insect in this photo is a prototype being developed by Martin Marietta engineers at the Oak Ridge National Laboratory in Tennessee. Purpose: to help Department of Agriculture experts track the migration of Africanized bees—the notorious “killer bees” that are advancing steadily on this country from the south.

The new strain of bees was generated in 1957 when Brazilian experimenters accidentally released queen honeybees they had imported from Africa. There is much controversy over just how much of a threat these Africanized bees pose, but they are known to be more aggressive than local strains, and unlike the gentler domestic honeybees are capable of swarming over large distances. A number of fatal attacks on humans and farm animals have occurred.

entomologists track the bees' migration northward into the United States.

The chief danger of the impending invasion, however, is the potential for disrupting beekeeping operations in the United States. Much more than honey is involved; every year some \$20 billion worth of agricultural food crops are absolutely dependent on pollination by honeybees.

To bug the bugs, researchers with Martin Marietta Energy Systems de-



Metal foam-core telescope mirrors, developed at the University of Arizona, weigh far less than conventional ones.

signed a special silicon electronic chip. About the size of a half-carat diamond, it contains a VLSI (very large-scale-integrated) microcircuit with its own power source, an array of tiny solar cells. It also contains a built-in micro-miniature infrared transmitter, whose beam can be tracked by ground-based transmitters as the bees buzz about their nefarious business. The information garnered in this way—a first for bee watchers—may help entomologists learn enough about the creatures' mating and foraging habits to halt their northward migration without the massive use of pesticides.

B-day—the time when the bees cross the Mexico-U.S. border—is now expected to occur next year.

Foam-core scopes

University of Arizona engineers and optical experts have built the first of a new generation of lightweight telescopes using metal mirrors with foam cores. Their 12-inch f/5 reflector, shown below, weighs only 10 pounds; a similar scope with a glass mirror would be closer to 50 pounds.

Metal mirrors are made by bonding two metal faceplates that are covered with a scratch-resistant nickel surface to an inexpensive metal foam that has been contoured to the desired shape. The surface is polished and then coated with aluminum for high reflectivity.

The technology has promise in areas that demand good-quality but inexpensive mirrors that can be made in quantity, such as laser communications and telephoto lenses for 35mm cameras.

High-protein corn

In a project sponsored by the U.S. Agency for International Development, researchers at Mexico's International Center for the Improvement of Maize and Wheat have created a new corn variety, quality-protein maize (QPM), that could dramatically improve the nutrition of many of the world's most undernourished people. Roughly half the protein in normal corn varieties completely lacks two essential amino acids, lysine and tryptophan. They are essential because they cannot be synthesized inside the body and thus must be obtained from

food. But QPM is nearly as good a complete protein source as skim milk, yet is identical in appearance and flavor to more common maize types with about half the nutritional value.

Neutrino mass test

The machine in the photo (right) is a spectroscope that will be used in a newly devised experiment at Lawrence Livermore National Laboratory to pin down the mass—if any—of that most elusive of particles, the neutrino. The experiment, one of 15 worldwide, will determine the mass indirectly, by measuring the energy spectrum of electrons that are emitted, along with anti-neutrinos, during the decay of a tritium atom. Tritium is a radioactive isotope of hydrogen, with three times the mass of an ordinary hydrogen atom.

Learning whether the neutrino has mass, and if so, exactly how much, is critical to validating a number of theories in modern physics, especially those in cosmology ["Hunting Neutrinos," May]. The head of the project, Wolfgang Stoeffl (seen in the photo), says "just knowing its mass can help scientists predict the ultimate fate of the universe. Will it expand forever? Or will it eventually collapse back on itself?"

The answers, from this experiment at least, should be available by 1990.

Rainmaker

The odd contraption in the photo at the bottom of the page looking like a horseless merry-go-round is a mobile sprinkler used by the U.S. Agricultural Research Service last spring and summer to simulate rainfall and aid in the study of soil erosion on crop land. The data collected will be plugged

This spectroscope at Lawrence Livermore National Laboratory may enable

into a new computer model to replace the 25-year-old Universal Soil Loss Equation. The object is to refine the criteria by which millions of acres of vulnerable land are taken out of ag-

physicists to solve a critical puzzle: Do neutrinos have mass? How much?

ricultural production for years at a time to conserve them.

Hypercubism

Ten times more cost effective than a conventional supercomputer and more powerful to boot—that's the advance billing for a new, massively parallel machine, the Mark III Hypercube, recently inaugurated at NASA's Jet Propulsion Laboratory after a five-year collaboration with the California Institute of Technology.

Hypercube refers to the complex geometry in which nodes, or processing units, are yoked together. The Mark III is to have 128 nodes, each with the power of 25 VAX minicomputers. Its peak speed will be two billion flops (floating point operations).

The hypercube mode of parallel computer architecture was pioneered in the late 1970s by Caltech computer scientist Charles Seitz and physicist Geoffrey Fox.

P 5



Mobile rainmakers like this one test agricultural land for vulnerability to soil

erosion. The information will help build a computer model for the USDA.

Electronics Newsfront

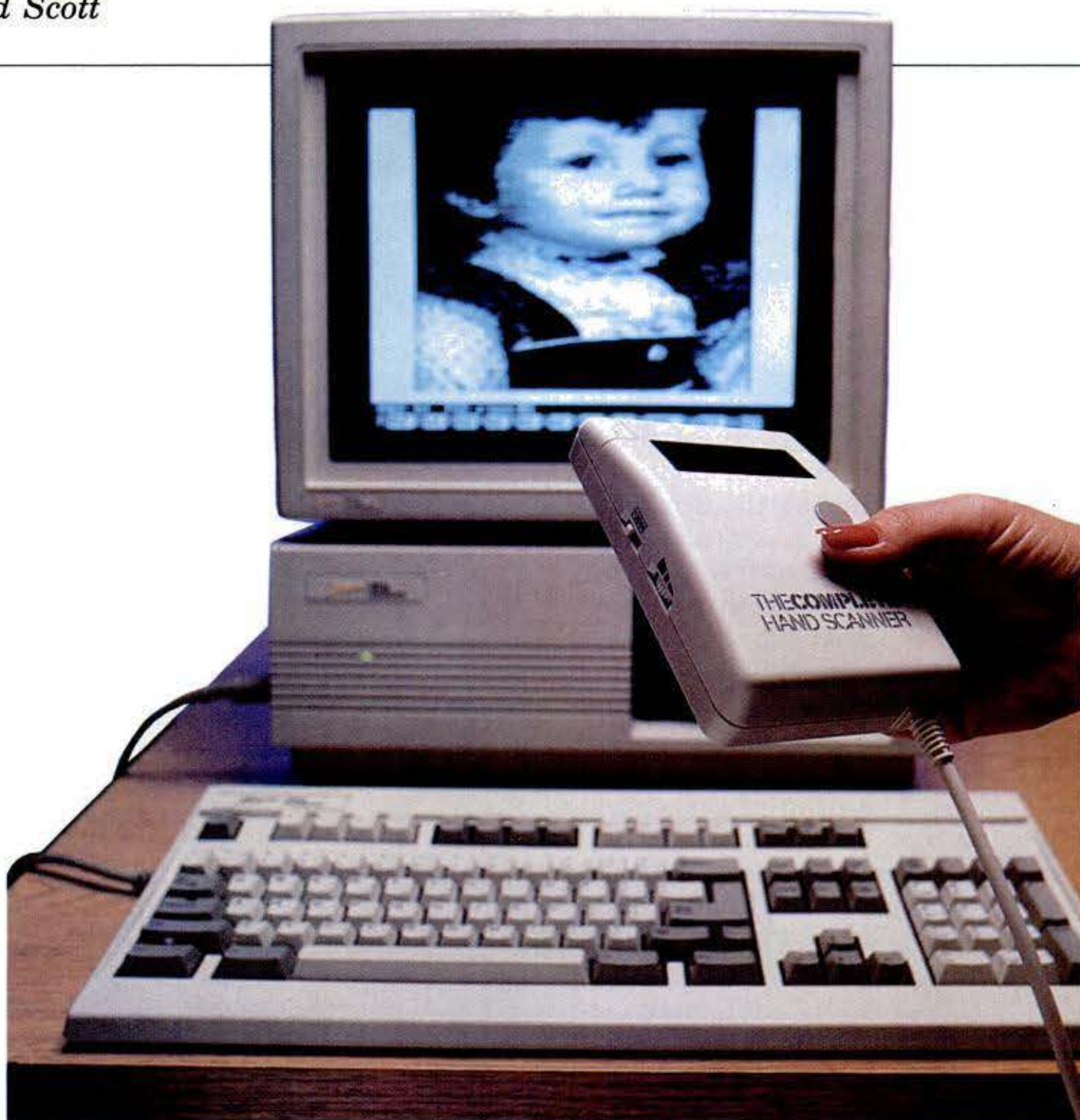
By WILLIAM J. HAWKINS with David Scott

Sight of hand

Swish. I just entered a picture of a canceled check in my computer for future reference. Swish. Now the computer holds the POPULAR SCIENCE logo for letterheads. Swish. A picture of my daughter Laura pops on the screen for the cover of her computer-generated birthday invitations. I'm using The Complete Hand Scanner, a clever hand-size device that's capable of "seeing" pictures, drawings, or text and sending them to a PC for editing, printing, or saving on a hard disk for recall.

For example, I made a copy of my signature for use with form letters. To do it, I put the scanner over a signed piece of paper and pulled the unit slowly over my writing. Then, using the included editing software, I made the script slightly bigger and erased a couple of lines I didn't like. Finally, I combined the signature with text from my word-processing program. Result: a form letter even Publishers Clearing House would be proud of.

One "editing" technique the scanner's maker doesn't tell you about is one I found by accident. I scanned a picture of a family crest that contains red letters and numerals at its center. When I looked carefully at the crest on the computer screen, I realized the printing was missing. I learned that red images absorb the red light that the scanner uses for surface illumination. The result: Scribble a red marker over the parts of a picture that you don't want, and they're



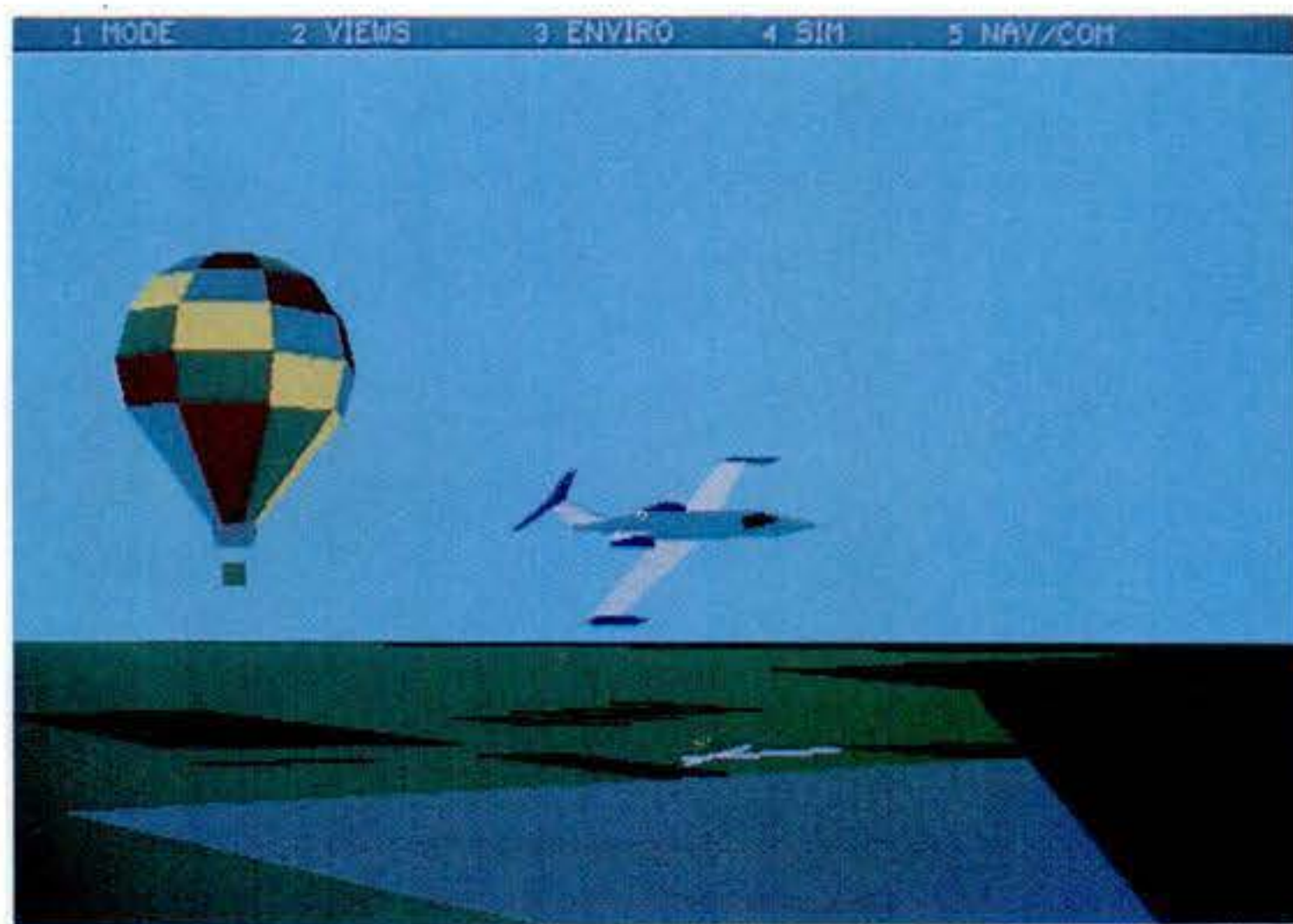
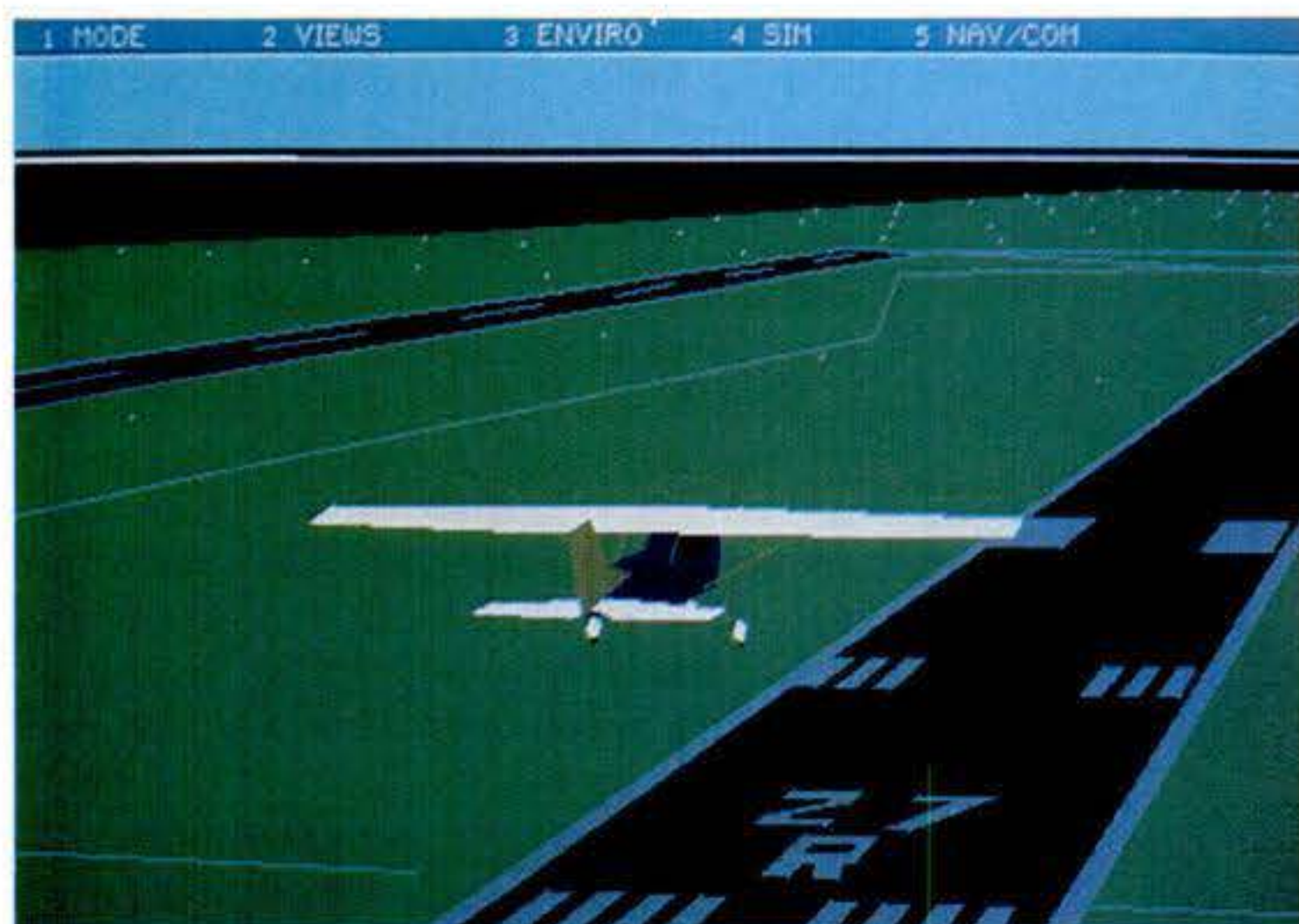
Side controls adjust the sensitivity of The Complete PC Hand Scanner.

gone when scanned into the PC.

While the 200-dots-per-inch scanner works well, it's limited to a 2.5-inch scan width. (The length can be up to 10 inches.) Multiple scans can be made and pieced together for wider pictures, but I found you'll need a mouse for any serious editing work. (Text is

scanned as a picture, so you can't edit it with a word processor.) Once an image is scanned, its black-and-white image can be colored using programs like PC Paintbrush and Dr. Halo II, or it can be sent to someone else via facsimile machine. The company offers a single-slot plug-in fax board

Continued



Microsoft's new version of Flight Simulator can use 640-by-350-pixel 16-color EGA and VGA graphics displays.

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When I first saw the data from our government's most prestigious laboratory charting their tests of TUFOIL, I almost fell off my chair.

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Their test data showed a steel on steel 4-ball surface friction of .029 with remarkably low wear. I rushed to my library, grabbed a lubricant handbook to see if my memory was correct. Sure enough! Teflon was listed at .04.

TUFOIL is not just a little slipperier than Teflon. It's a lot slipperier than Teflon. There was the handbook data right in front of me!

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People like you send us letters raving about improved starting, smoother operation, spectacular acceleration, gas savings and much longer trouble-free engine life.

TUFOIL has been written up in prestigious scientific journals, newspapers such as the Wall Street Journal, Boston Globe, New York Times and Christian Science Monitor and tested in Universities and laboratories all over the world. The results are overwhelming! As far as we can see, TUFOIL has the lowest

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TUFOIL means big savings for you, your car and your machines! So rush your order now and get these marvelous benefits.

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- Makes engines run better, last longer

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"My acceleration was also noticeably increased and where my normal engine running temperature had been with the needle halfway between HOT and COLD, it is now only one third of the way in between."

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See NASA Tech Briefs for technical details, 1986, 1987 and 1988.

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(see "Don't Mail It...Fax It" this issue) that works with the single-slot, half-size scanner board.

Made by The Complete PC (521 Cottonwood Dr., Milpitas, Calif. 95035), the PC-compatible scanner is \$249.

Up, up, and away—again

It's been four years since Flight Simulator, a computer program that puts you behind the controls of an aircraft, began challenging the dexterity and

flight knowledge of even licensed pilots. The program is fun, but it's more well-known for its technical accuracy. (I always crashed because of *something* I forgot to do.) Now there's a new version that lets you fly everything from a Gates Lear Jet to a crop duster, and, using a new 3-D feature with multiple windows, you get to see views from different perspectives. Made for PC-compatible machines, it's \$50 from Microsoft (16011 N.E. 36th Way, Redmond, Wash. 98073-9717).

Clip-on computer tester

The matchbook-size black box straddles the parallel interface chip on any PC that uses an 80286 or 80386 microprocessor. Then, according to inventor Jean-Claude Mermoud, the device trouble-shoots the entire computer system. The unit uses an LED to display codes that represent faults in specific integrated circuits, sockets, or conductors. Shown at the Geneva Inventors Exhibition, the \$200 Logimer is available from InterDatapro S.A., 1681 Villagiroud, Switzerland.

Feed it just about anything.

Pick a board. Any board. With the 10" Motorized Table Saw from Delta, you can turn it into moulding, shelving and fine furniture.

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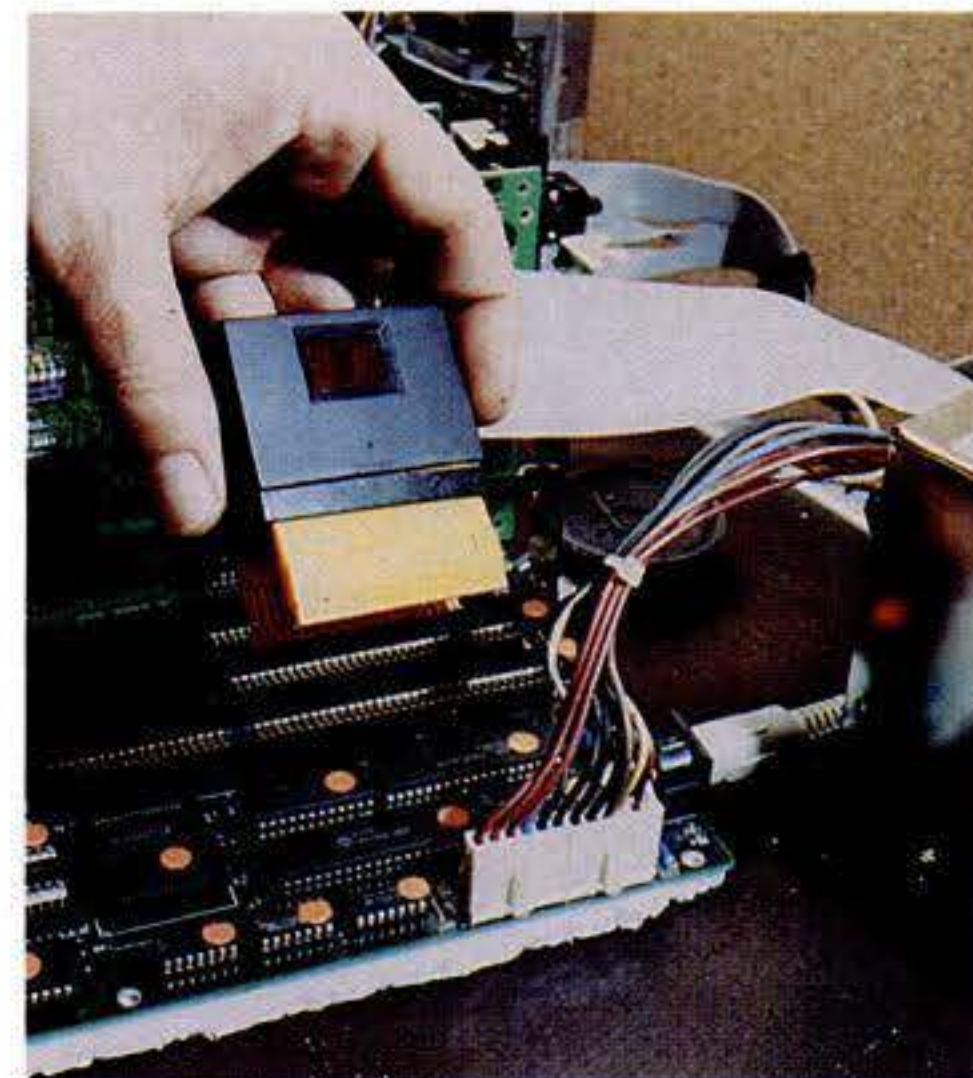
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Clip Logimer to one PC chip to quickly diagnose any computer ailment.

No cranks, just speakers

Sometimes it's impossible to put a speaker just where you want it in an automobile. So Ford Motor Co. had another better idea: The company designed the car around the speaker system. Well, almost. "Our audio engineers worked closely with the Thunderbird and Cougar designers," says Larry Lopez, executive engineer of Ford Audio Systems group, "enabling us to place speakers and controls in optimum locations inside the cars." The result is a high-quality Ford JBL sound system with CD and DAT options... plus electric windows. Why electric windows? "The audio engineers wanted the speakers up high in the doors for better response," Ford Audio Systems planning and marketing manager Don Duncan told me in Detroit. "That meant there was no room for window cranks, so we had to make electric windows standard."

Sign of the times?

Matsushita has begun exporting its Panasonic TVs from its Franklin Park, Ill., manufacturing facilities. To where? Japan. **P 5**

OLYMPIC ZINGS THE BLUES

UV Plus™ Lenses that Block Blue Light for increased contrast & definition

100% ULTRAVIOLET PROTECTION

The new UV Plus™ lens by Olympic Optical absorbs 100% of the sun's harmful ultraviolet rays as well as offering the advantages of a blue light filter. Blue light is not easily focused by the human eye because of its position at the very end of the visible light spectrum. Blue light is also easily scattered by dust, fog and haze. By filtering blue light the remarkable new UV Plus™ lens greatly increases contrast and definition. Through them you'll see razor sharp detail and your eyes will experience a new feeling of relaxation. Pilots, race car drivers, shooters, and golfers are only a few of the outdoor enthusiasts who report increased visual acuity with UV Plus™ lenses.

The amber/orange UV Plus™ lens is offered in a variety of quality frames at surprisingly affordable prices. Most frames are available with UV Blocker™ lenses for ultraviolet protection in gray or brown tints. Flip-up clip-ons are

available with either regular UV Blocker™ polycarbonate lenses or optical quality CR-39 UV Plus™ lenses.

If you want the ultimate sunglass you need Olympic's new Polar Blue™ sunglass which offers all the benefits of the UV Plus™ lens with the added benefit of a polarizing filter for protection against reflected glare. Polar Blue™ lenses are made of optical quality CR-39 and are fitted in a mat gray finish Italian made frame. Absolutely the ultimate driving and fishing glass. Olympic Optical has been supplying the optical needs of police and sportsmen since 1976 and its products are sold in 50 states. You can order with confidence — if not completely satisfied, you may return your purchase within 10 days for a full refund.

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The Olympic shooting glass. Optical quality frame w/rubber covered cable temples and virtually indestructible polycarbonate lenses. Specify gold frame with gray or yellow UV Blocker™ lenses **\$19.95** or black frame with UV Plus™ lenses **\$29.95**



2020

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278

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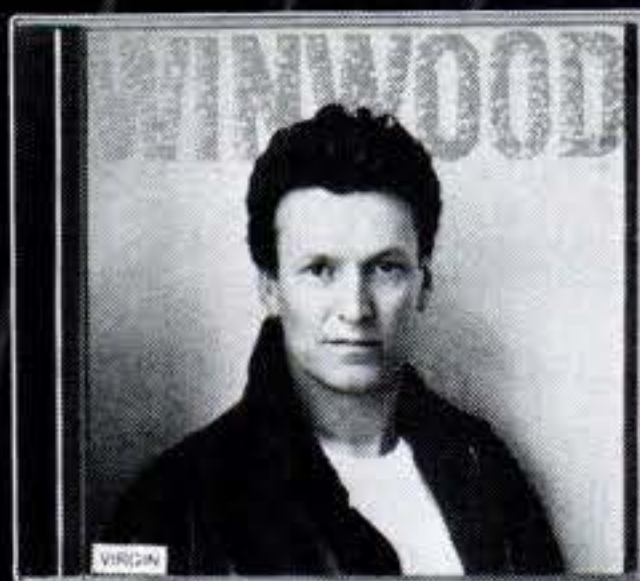
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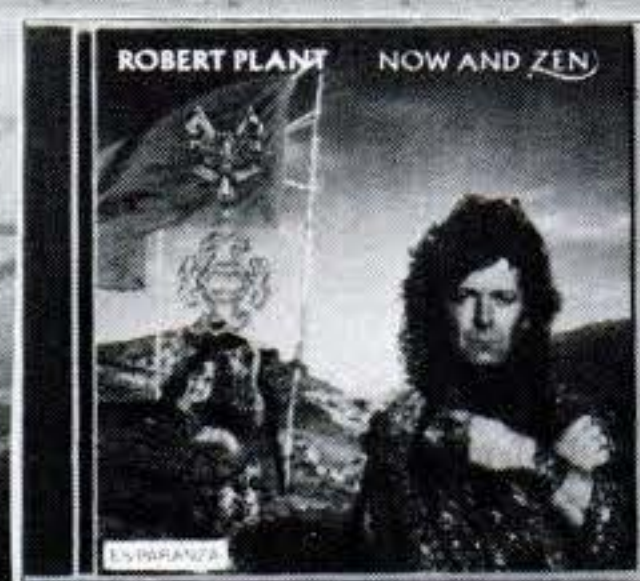


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A Sound Investment



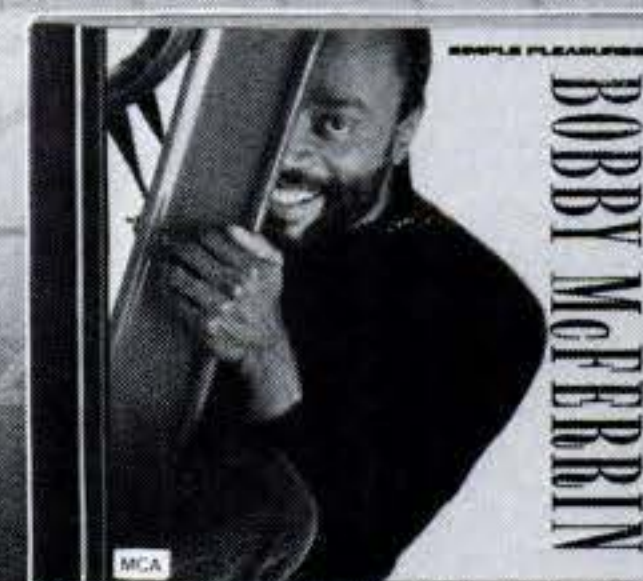
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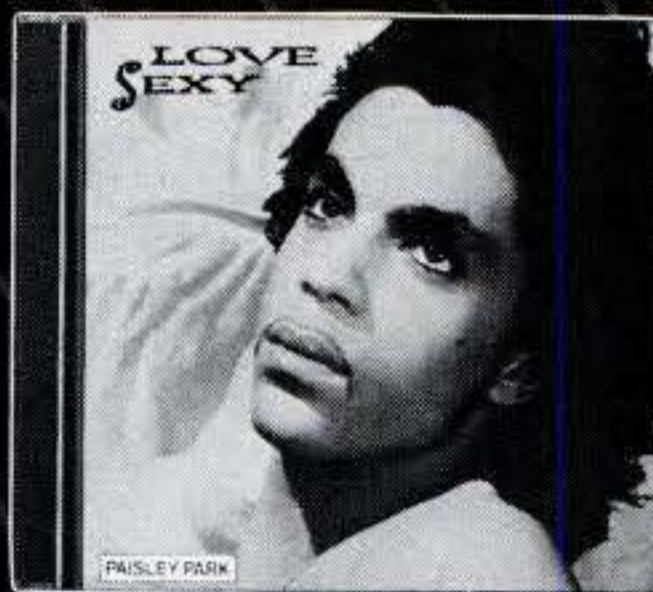
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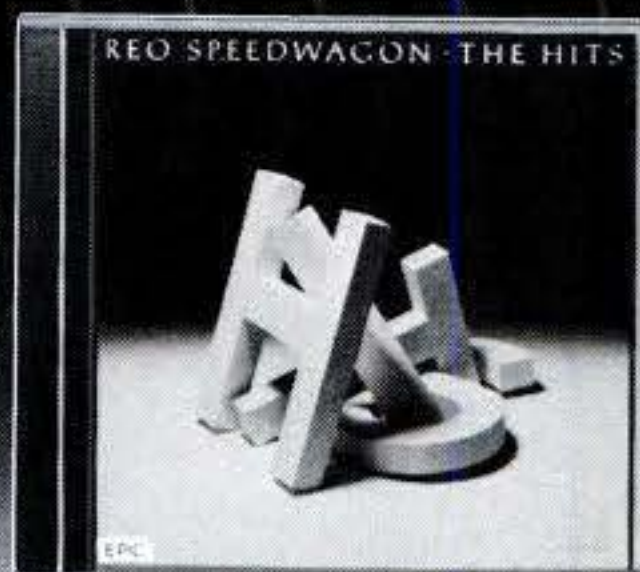
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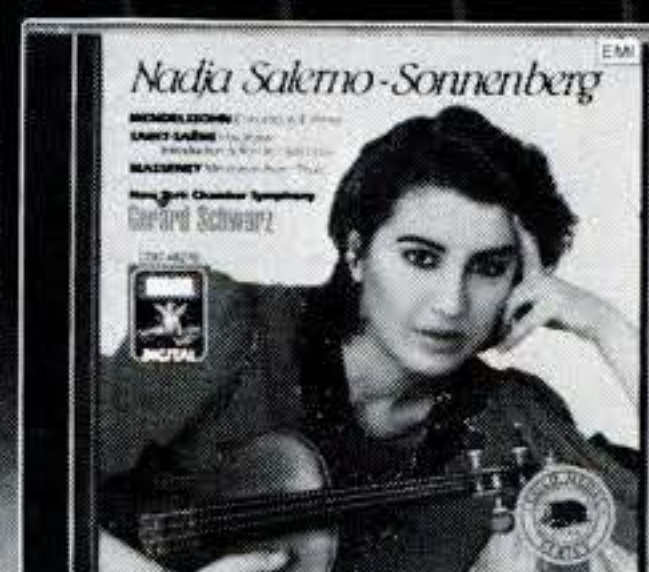
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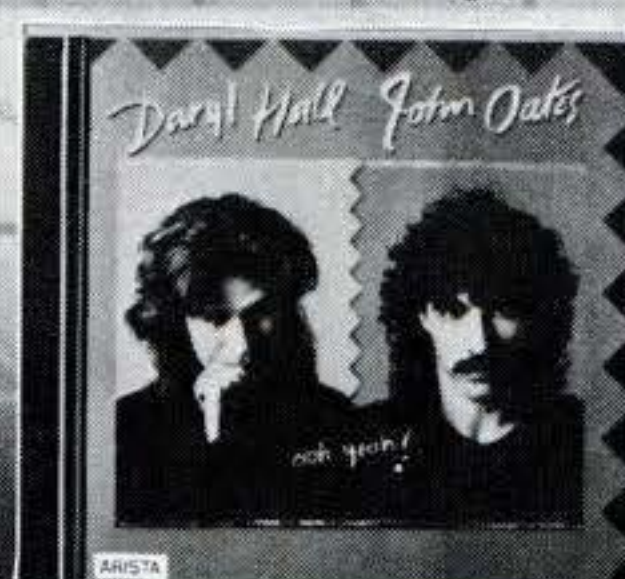
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Dashing fastback

BILLESLEY, ENGLAND

The British are coming—again, and this time with a little more dash. From the people who brought you the Sterling luxury sedan [April '87] comes the shapely Vitesse Fastback, complete with several major mechanical assemblies from Honda production lines.

What's new, aside from the sleek body styling, is the silky, surging power of the Honda 2.7-liter 24-valve V6, blasting out 177 horsepower. With the Vitesse's slippery 0.30 coefficient of drag and discreet rear spoiler, it's easy to see why the car's name, which is French for speed, is appropriate.

On a 200-mile run around the rolling hills of the English heartland, I clocked a quick 7.7-second 0-to-60-mph acceleration, but was unable to confirm the claimed 140-mph top speed. Speed-sensitive power steering and the Vitesse's sport suspension with stiffer shocks and anti-roll bar accounted for the tight, responsive handling on twisty country roads. The inclusion of anti-lock brakes and a dual-mode four-speed automatic transmission, offered as no-cost options, is designed to project a dynamic, high-profile image, which contrasts with the car's understated wood and leather interior.

Five-door convenience

Unlike the Acura Legend coupe, which shares the same engine, the Fastback has a five-door body style, including the high-rise hatch with its convenient electric release. There is ample room for passengers and gear, and the rear bench seat folds to open up nearly 50 cubic feet of storage space, accommodating a 5.7-foot-long load with ease.

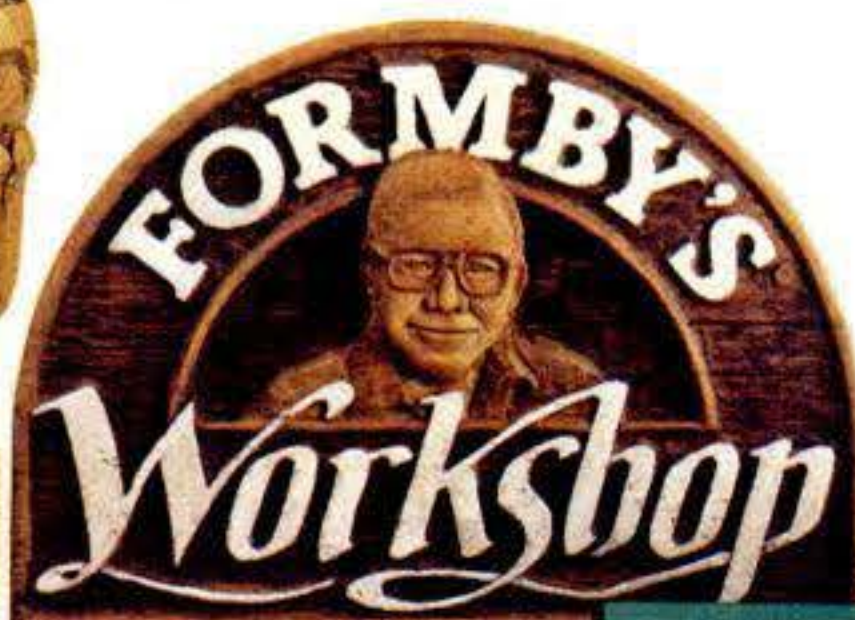
Fully loaded extras include infrared remote locking, anti-theft alarm, and electric tilt/slide sun roof. According to the Vitesse's American importer, Austin Rover Cars of North America, the car will be named 827 SLi in the United States and will take its place alongside the 825-series Sterling sedans. The Vitesse, only now starting to appear on European roads, will be launched in the United States around New Year's and have a sticker price of around \$20,000. —David Scott

ORDINARY PEOPLE. EXTRAORDINARY RESULTS.

Paint Remover and went to work. "Formby's Paint Remover easily removed layers of old paint, without hurting the wood," reports Bob. Indeed, at the Formby's Workshop we're particularly proud of our Paint Remover that's tough on paint—but gentle to your wood.

If you'd like more information, give us a call at 1-800-FORMBYS. You can always turn to the Formby's Workshop—where we always help things turn out right.

Nothing works like things from The Workshop.



Results that come from a unique paint remover which attacks the paint and defends the wood.

The ordinary person: Bob Sikora, mechanic. The extraordinary result: an armchair that deserves a hand.



"This chair went from a garage to my living room."

When Bob Sikora found this now-striking oak chair, it was submerged under decades of old paint. But Bob spotted the potential. So he grabbed a can of Formby's®

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#4000 SINGLE SPEED...\$59.99

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*Rebates subject to manufacturer's stipulations.

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Indoor, outdoor.

shop-vac

SALE

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SALE

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CASSETTE.**

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Electronic tuning, LED readout, and clock. Auto reverse. 8-station preset. Seek.

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PIONEER

**KE1011 DELUXE ETR AM/
FM STEREO/CASSETTE.**

Seek and local/distance switch. 18 FM and 6 AM station memory. LED clock and readout.

SALE **169⁰⁰**



SONY

**ESR-11 AM/FM STEREO/
CASSETTE.**

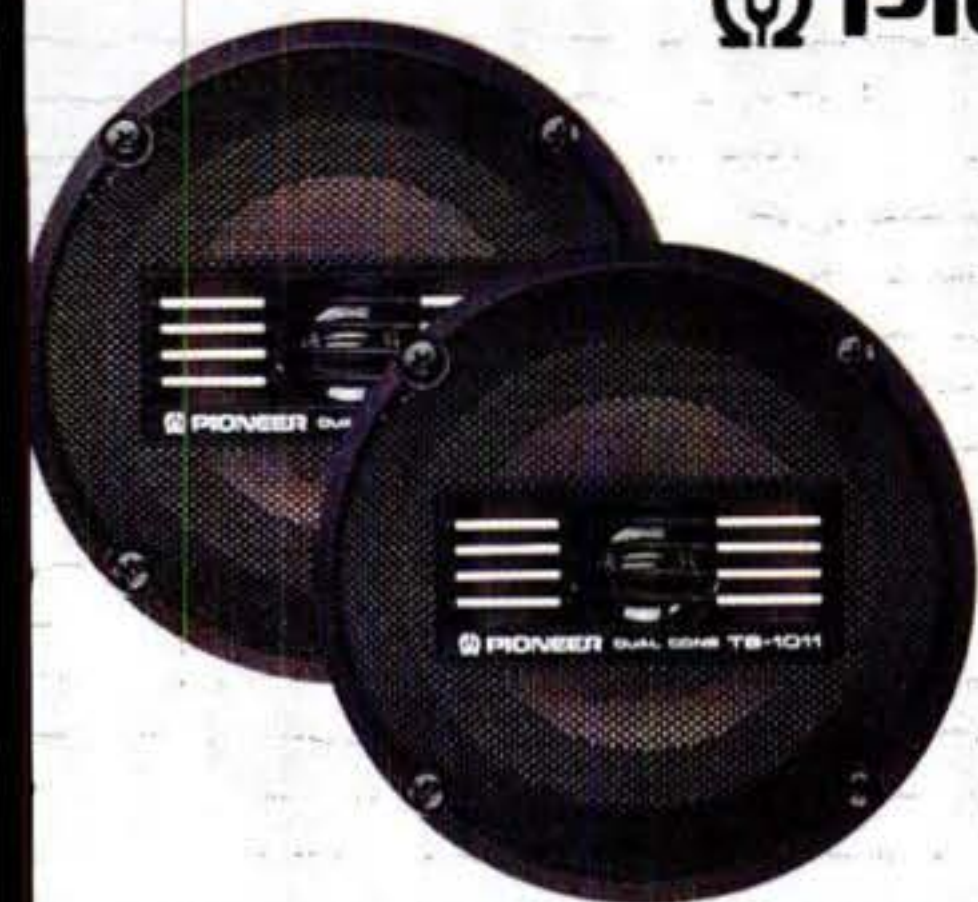
PLL quartz tuner, 18 station presets, seek function.

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electronics at famous K mart prices.

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TS-1011 4" DUAL CONE SPEAKERS.
4" strontium magnet Maxxial™ door-mount speakers with 60-watt output.

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Cobra



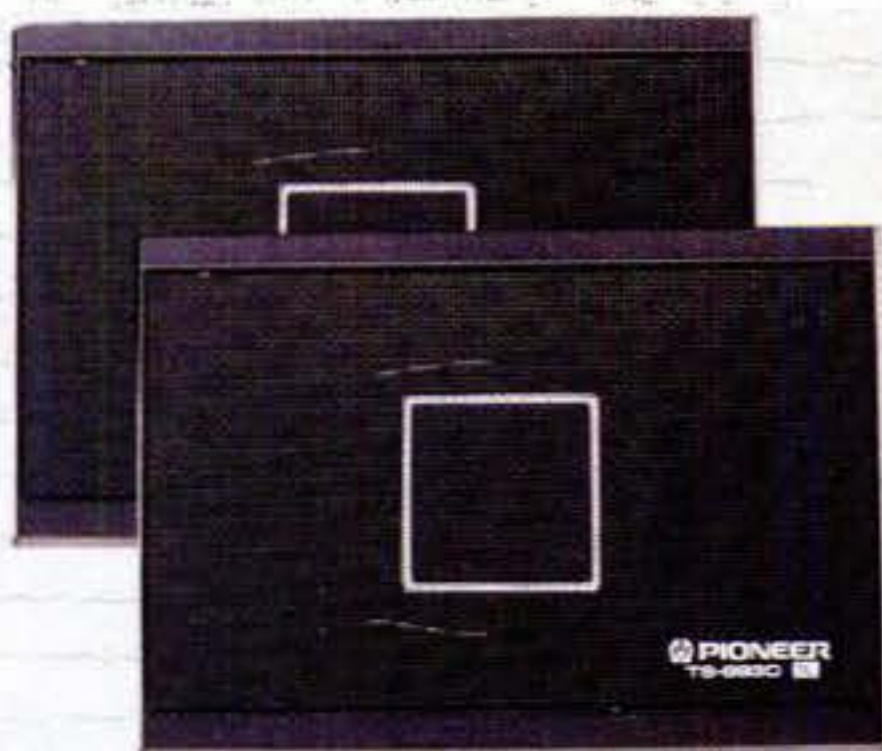
#C20 40-CHANNEL CB RADIO.

Compact. Squelch, digital readout. Electronic tuning, LED signal strength meter, and instant emergency channel 9.

SALE
59⁰⁰

TS6930 6" X 9" DUAL CONE SPEAKERS.
Digital-ready. Maxxial™. 120-watt output. 7.8-ounce strontium magnets.

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ES-S52 5 1/2" TWO-WAY COAXIAL SPEAKERS.
40 watts maximum music power and shallow mounting depth.

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ES-S92 6" X 9" TWO-WAY COAXIAL SPEAKERS.

80 watts maximum music power.

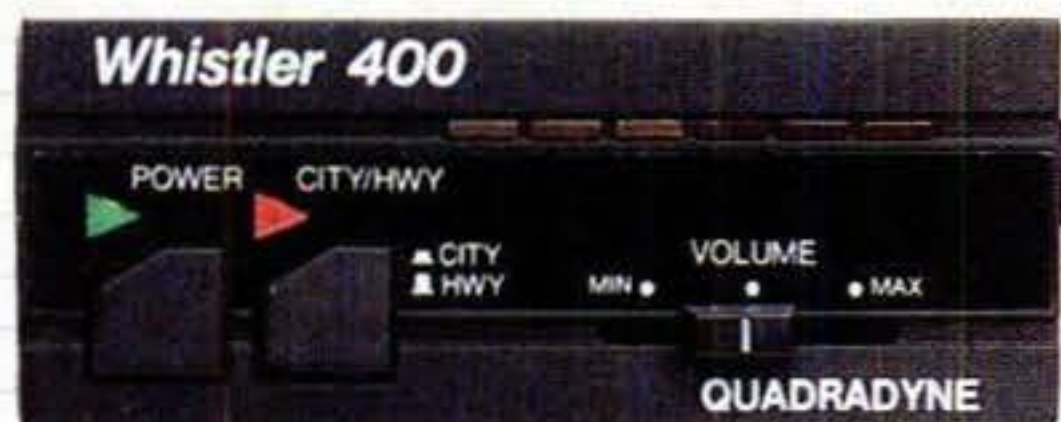
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SPECTRUM 1 DELUXE RADAR DETECTOR.

Mounts on dash or visor. Digital display, filter mode, and three-position volume control. Available in most stores

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DURAKON
RubberQueen

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TRUCK BED MATS.

Custom-fit heavy-duty rubber. Sizes to fit many trucks.

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TRUCK VENT SHADES.

Keeps rain out, lets fresh air in. Eliminates window fogging and aids in defrosting. For most pickups. Mfr. may vary.

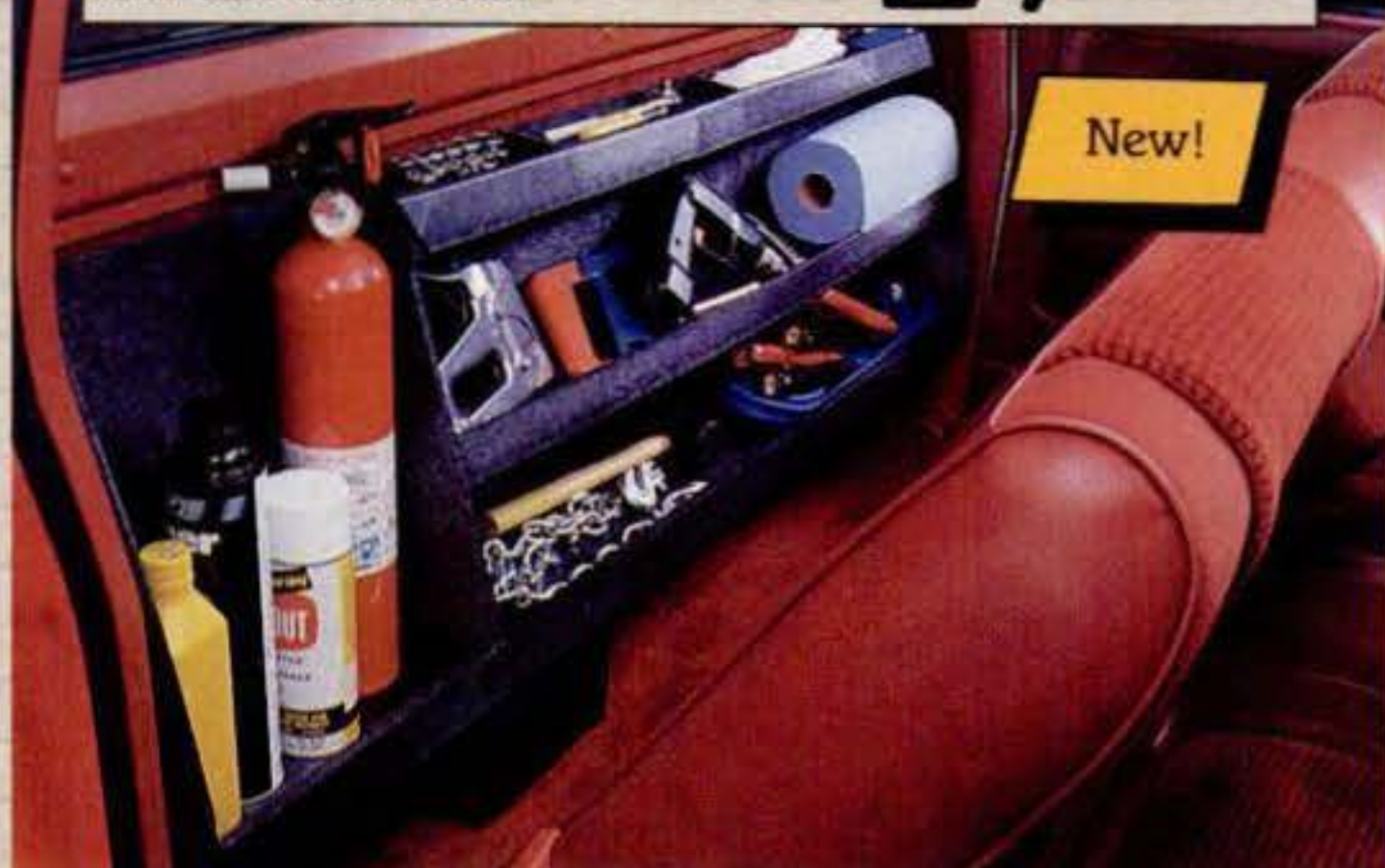
SALE
7⁹⁷



TRUCK CAB ORGANIZER.**
Rugged molded construction, both vertical and horizontal storage space. Fits behind any full size truck seat.

RubberQueen

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27⁹⁷



New!

VINYL TRUCK TOTE.**

Fits behind seat. Stores tools, maps, and more. Fits all types of pickups.

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**Merchandise not included.

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SIX-INCH OFF-ROAD LIGHTS.
6", 100-watt, round halogen truck light.

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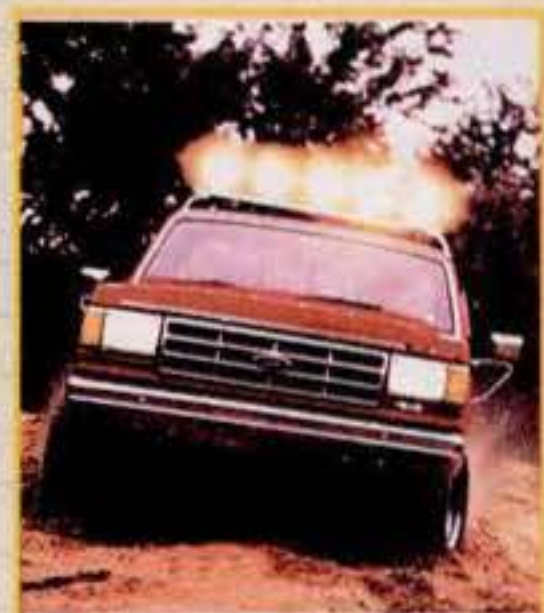
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FOG LIGHT KITS.
Quartz halogen amber or clear fog lights for most trucks, vans, or cars. Includes switch and wiring.

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KENCO

**STAINLESS STEEL
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For most trucks.
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Available in most stores.

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**JPT 1802 PICK-UP
TRUCK SPEAKERS.**
Matched, 150-watt
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DURANGO TRUCK SEAT COVERS.

Deluxe, Western-styled form-fitted bench or bucket covers for mini or standard trucks.

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SEAT COVERS



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Twin front mats for full-size pickups. Mfr. may vary.

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DELUXE VELOUR SEAT COVERS.

Soft and comfortable. Deluxe seat cover in sizes for two- or four-door and bucket seats.

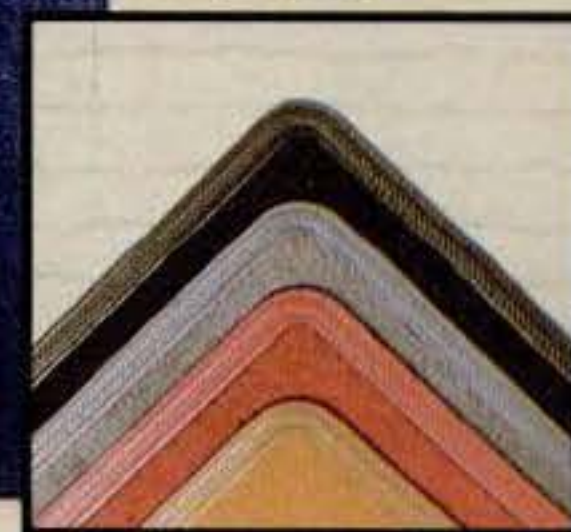
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PKG.



FOUR-PIECE CARPETED MAT SETS.

Twin front and rear plush carpeted mats. Mfr. may vary.

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Allison

PLAYBOY SEAT COVER.

Hi-pile pull-on cover stretches over regular and hi-back bucket seats. Machine washable.

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EACH



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CAR COVER

DRIVERS SIDE ACCESS ZIPPER



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FABRIC NO. 100
COLOR NO. 11-11-11

NYLON CAR COVER.

Protect your car in summer or winter. M or LG. Available in most stores.

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HEAVY-DUTY TRAILER KIT.
1060-lb. capacity. Includes
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For hauling or yard work.
Assembly required.
Available in most stores.

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**DELUXE AIR
COMPRESSOR.**
12-volt, 225 psi com-
pressor with
pressure gauge,
emergency light,
and warning
flasher.
Model LFB 225.



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TWO-TON FLOOR JACK.
Compact hydraulic floor jack
with heavy-duty construction.
Model 41-07.
Style and mfr. may vary.

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**THREE-TON JACK
STANDS...SALE 17.97 PAIR**

**CR1000 MECHANICS
CHEST AND
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CABINET.**
6 drawer chest with 2
drawer cabinet and
storage bin. Great for
basement or garage.

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1/4" and 3/8" metric or SAE in metal case.

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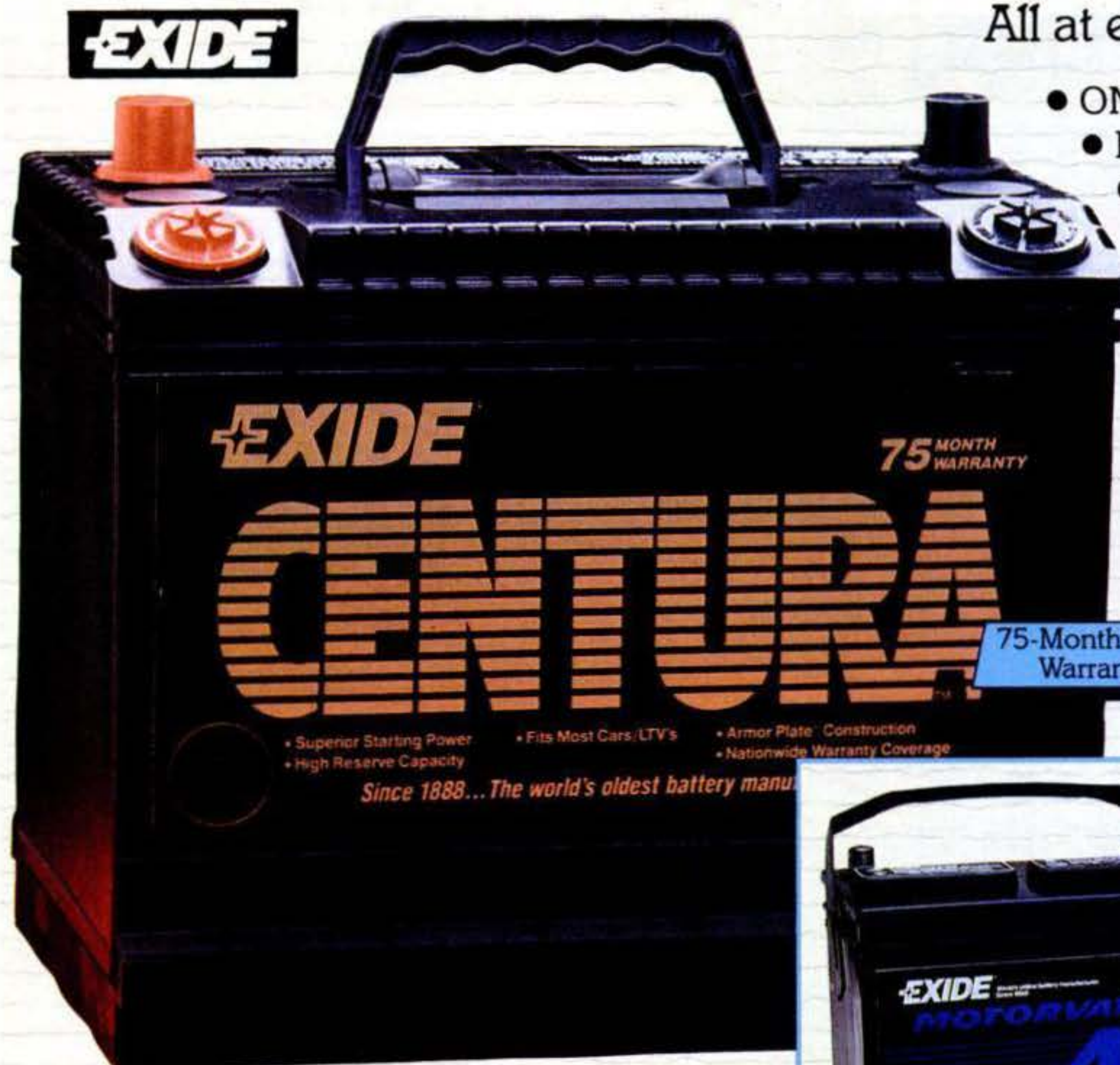


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CENTURA 850.
Our most powerful battery.
Delivers 850 CCA's. Sizes for
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CENTURA 650
WITH 650 CCA's... 49.77

45-Month
Warranty*



**MOTORVATOR 45
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Delivers up to 420 CCA's.
Sizes for many U.S. and
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USA

We offer a complete line of batteries for
cars, trucks, motorcycles, lawn and
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Installation available in stores with
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**DELUXE ROLLAROUND
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For fast charging and boosting
6- or 12-volt batteries. 200-
amp starting power, one hour
timer, and more.
Mfr. may vary.

Schumacher

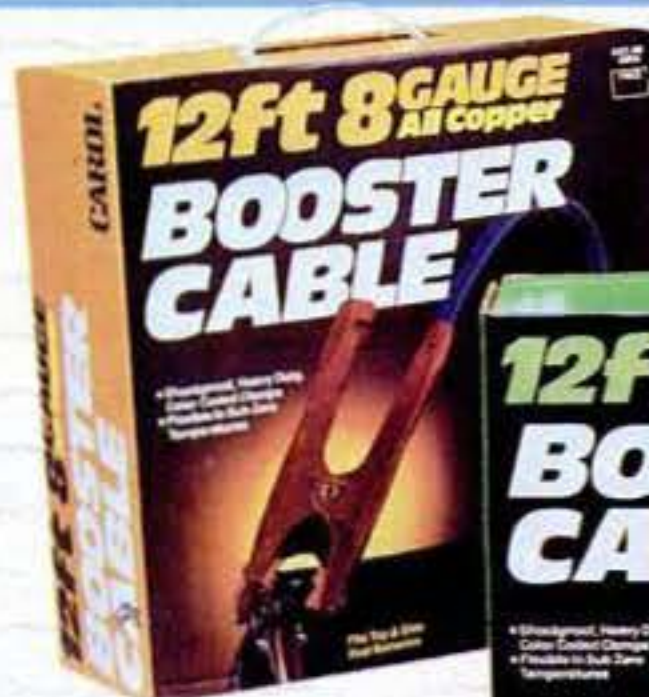
SALE
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12-VOLT STARTER/
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8-gauge heavy-duty, tangle-
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**MONRO-MATIC PLUS™
SHOCK ABSORBERS.**
Heavy-duty gas-charged
shocks for many U.S. and
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Heavy-duty original equipment
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Carry out each.

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For light-duty trucks. Popular
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**\$3.00
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The ultimate in riding comfort.
Gas-charged. Sizes for many U.S.
and import cars. Carry out each.

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Rebate***

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SUPER STRUTS.

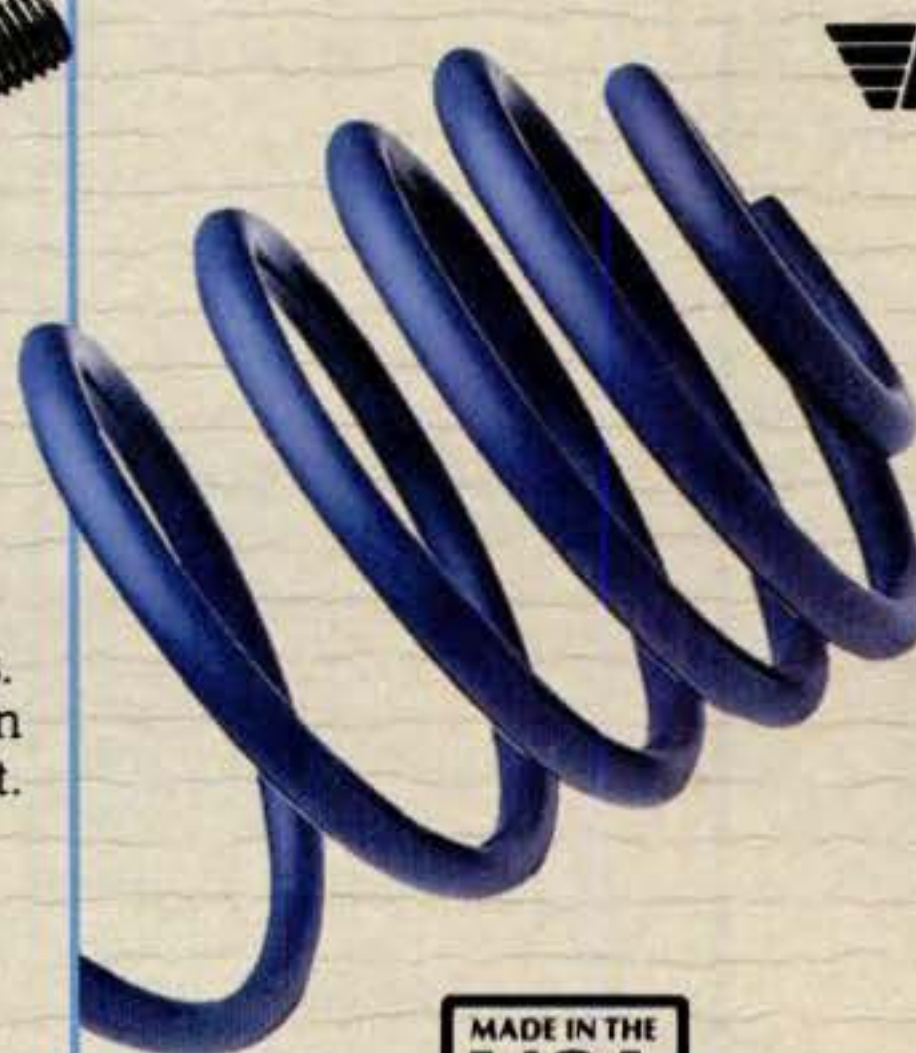
Fronts for many U.S. cars.
Alignment recommended on
many cars with strut replacement.

GM A&X CARS...54.47
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CHRYSLER AND K CARS.

GAS-MATIC
STRUTS \$10.00
MORE PER SIDE.

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**LOAD HANDLER
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Supports up to 1000
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Restores car to
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GARAGE AND DRIVEWAY CLEANING KIT.
Removes oil and cleans. Spray on and wash off.

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*Details in store.

16 fl. oz. degreaser and 2.5 lb. net wt. absorber.



GALVANIZED GAS CAN.
Five-gallon with flexible spout.

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Mass. state approved.



50¢ Rebate

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ONE WIPER BLADE OR TWO REFILLS.
Popular sizes to fit many U.S. cars and light trucks. 17"-19".



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ARMOR ALL PROTECTANT.
Protects and beautifies. 16 fl. oz.

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64 OZ. PROTECTANT...
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FRAM OIL FILTERS.
Popular sizes for many U.S. and import cars. Model PH8A.

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Cleans greasy, oily, dirty hands. 14 oz. net. wt.

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97¢



STP SUPER CONCENTRATED FUEL INJECTOR CLEANER.
12-fl. oz.

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STP

STP LIQUID FUEL INJECTOR AND CARB CLEANER, 12-fl. oz....
SALE 1.27

Amoco ONE-GALLON UNIVERSAL ATF.



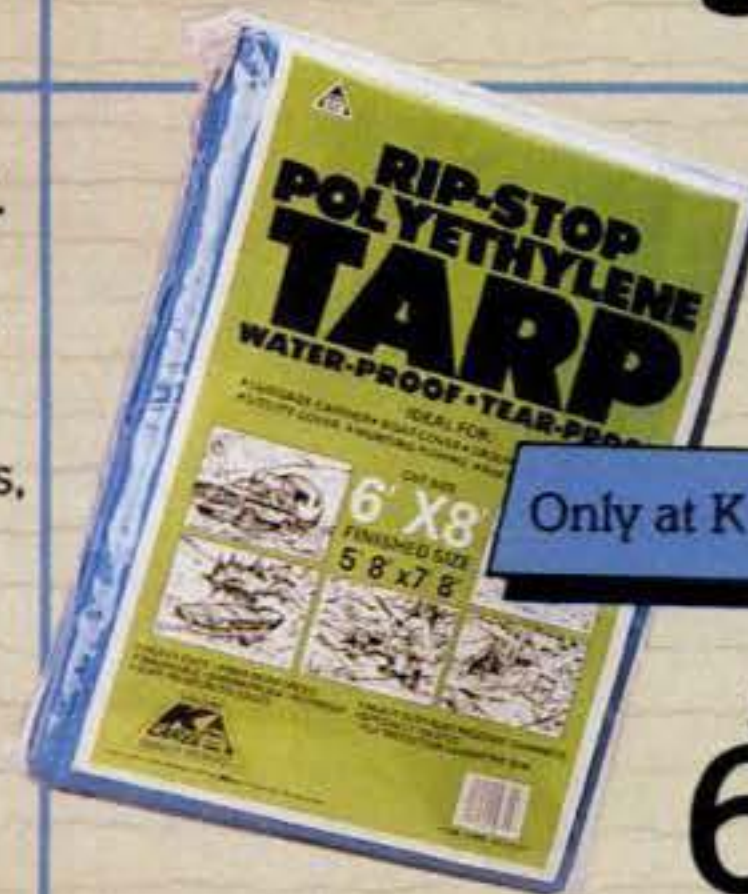
Multi-function transmission fluid for passenger cars, trucks, and vans.

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Only at K mart!



22" TRANSFUNNEL...
SALE 1.27



Only at K mart!

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POLYETHYLENE TARP.
8' x 10'. Waterproof, tear proof, shrink and rot-proof. Rust-resistant grommets.
10' x 12' TARP...SALE 9.97



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re in just one place, The Saving Place.



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KRYLON PAINT.
12 oz. Choice of colors. Interior, exterior spray enamel. Use on wood, metal.

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RUST-OLEUM



RUSTOLEUM.
12-oz. Choice of colors. Fights rust. Excellent chip and peel resistance. Use on wood, metal, wicker.

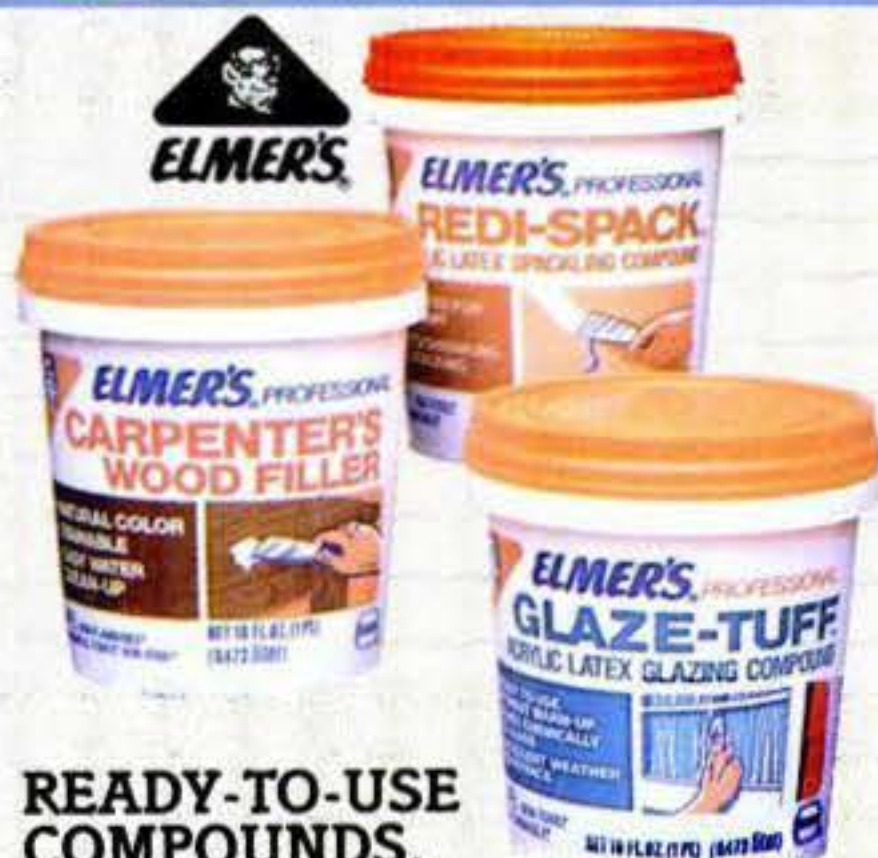
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2 FOR \$5⁰⁰

SILICONE SEALERS.
Mildew- and moisture-resistant, paintable, and easy to clean up.

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10.3 oz.



DOW CAULK
SALE
3⁹⁷
10.3 oz.



READY-TO-USE COMPOUNDS.
Patch small holes and cracks. Pint. REDI-SPACK, WOOD FILLER OR GLAZETUFF.

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#226 POWER SCREWDRIVER.
Drives and removes screws, nuts, bolts, 3-hour rapid charge, cordless.

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CORDLESS SCREWDRIVER.
Adjustable clutch, rechargeable. Foldable. Forward and reverse.

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42" CEILING FAN.
Antique brass or white, flush mount. 3-speed, reversible blades. Light kit adaptable.

SALE
31⁹⁷

52" HUNTER CEILING FAN.
Three-speed reversible. Stronger hanger system reduces noise. Non-tarnishing, scratch-resistant brass finish.
• Bright brass
• White and brass
• Antique brass

SALE
66⁸⁸



POWER ROLLER PLUS.
Automatic paint feed. 18" extension for ceilings.

SALE
69⁰⁰



HEAVY-DUTY SPRAYER.
Sprays up to one gallon of latex in 20 minutes. Includes accessories.

SALE
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Don't pay more for the best brand names — shop K mart

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AUTO
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**7548 VARIABLE SPEED
M47 JIGSAW.**

Variable speed
with built in
sawdust blower.

SALE
27⁹⁷

BLACK & DECKER

9527 AIR STATION.

Built in pressure gauge. 120 p.s.i.
capacity. Three inflator nozzles.

SALE
49⁹⁷



BLACK & DECKER

7144 3/8" VSR 47MM DRILL.
M47 Series™ motor for more
power, higher torque and easier
handling. Chuck key clips on
cord to prevent loss.

BLACK & DECKER



SALE
27⁹⁷



7308 7 1/4" CIRCULAR SAW.

1 1/2 horsepower. Includes
wraparound steel shoe,
two handles for
greater control, and
combination blade.

SALE
36⁹⁷

BLACK & DECKER

WORKMATE 200.

Dual heights for workbench or
saw horse. 23" rule on front
jaw for measuring. Holes
provides storage for hand
tools.

BLACK & DECKER



SALE
49⁹⁷



9422 7 1/2" BAND SAW.

10" tilting table.
Lockable on/off
switch.

SALE
89⁹⁷

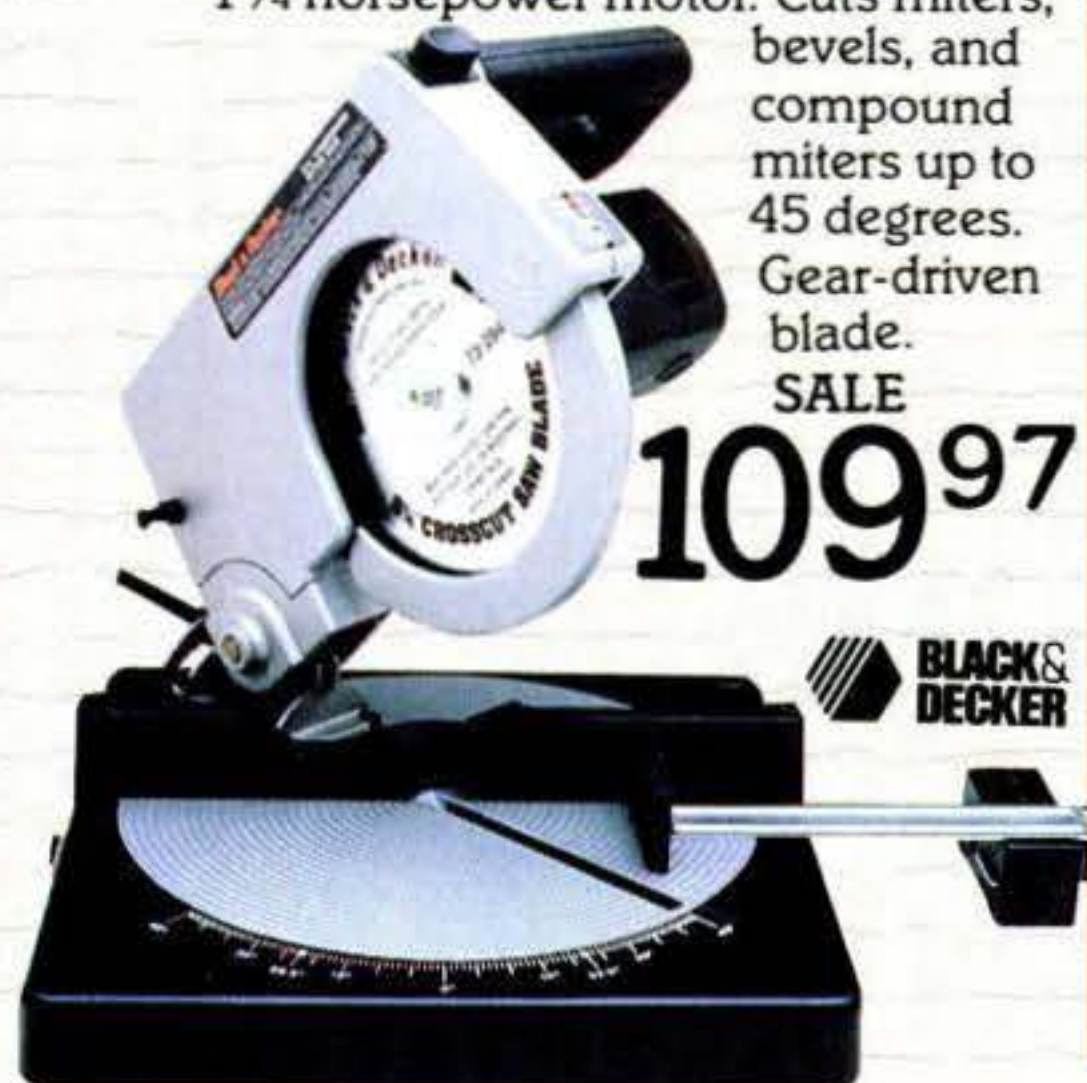
BLACK & DECKER

**9425 8 1/4" MITRE SAW
WITHOUT LEGS.**

1 1/4 horsepower motor. Cuts miters,
bevels, and
compound
miters up to
45 degrees.
Gear-driven
blade.

SALE
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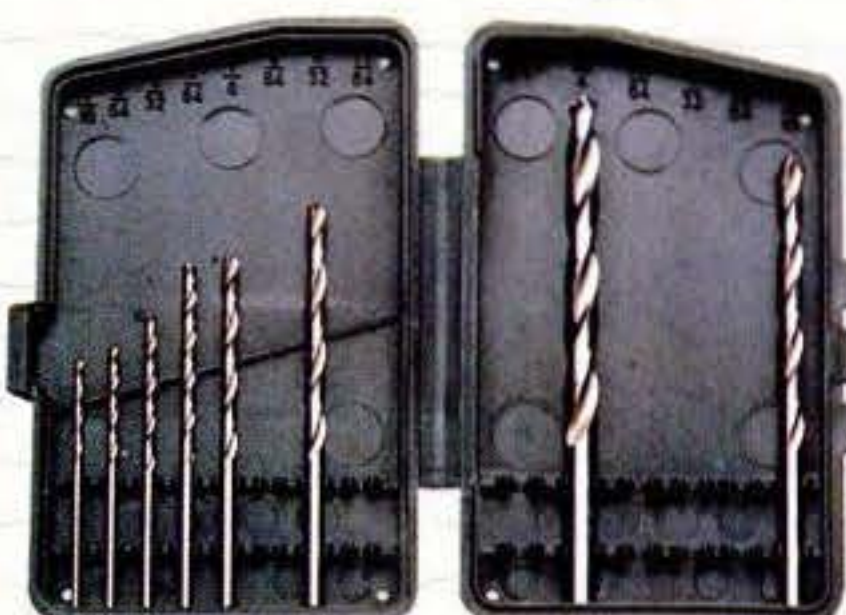
BLACK & DECKER

Bullet

BULLET™ DRILL BITS

Drill up to 4 times faster in metal
and last up to 7 times longer.
8-PIECE SET.

SALE
9⁹⁷



BLACK & DECKER

Piranha

**PIRANHA® CIRCULAR
SAW BLADES**

Cut faster and last up to 50
times longer than
steel blades.

SALE
6⁴⁴



BLACK & DECKER®
**\$3 MILLION
POWERHOUSE
SWEEPSTAKES**

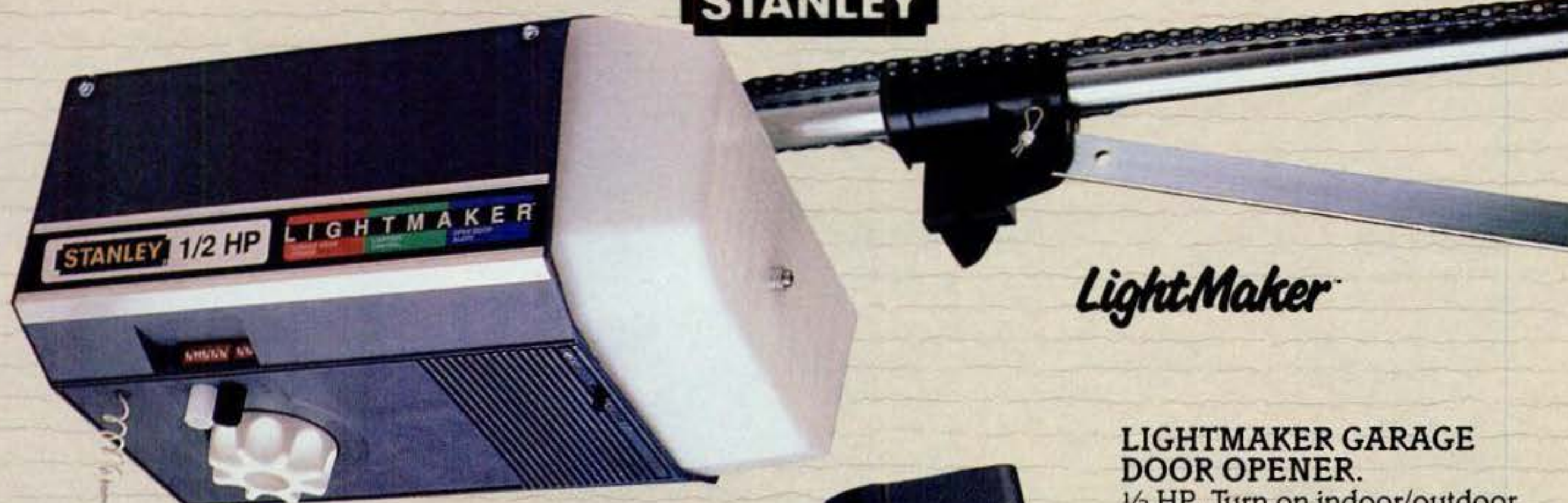
See store for details.

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for all of your home needs.



STANLEY



LightMaker

LIGHTMAKER GARAGE DOOR OPENER.

1/2 HP. Turn on indoor/outdoor house lights from the safety and convenience of your own car. Variable light time delay. Transmitter and one lamp module included.

SALE

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Home light control

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On/Off lamp module

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Switch module

SALE 15.88



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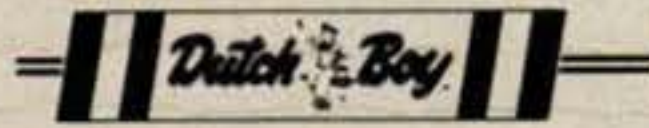
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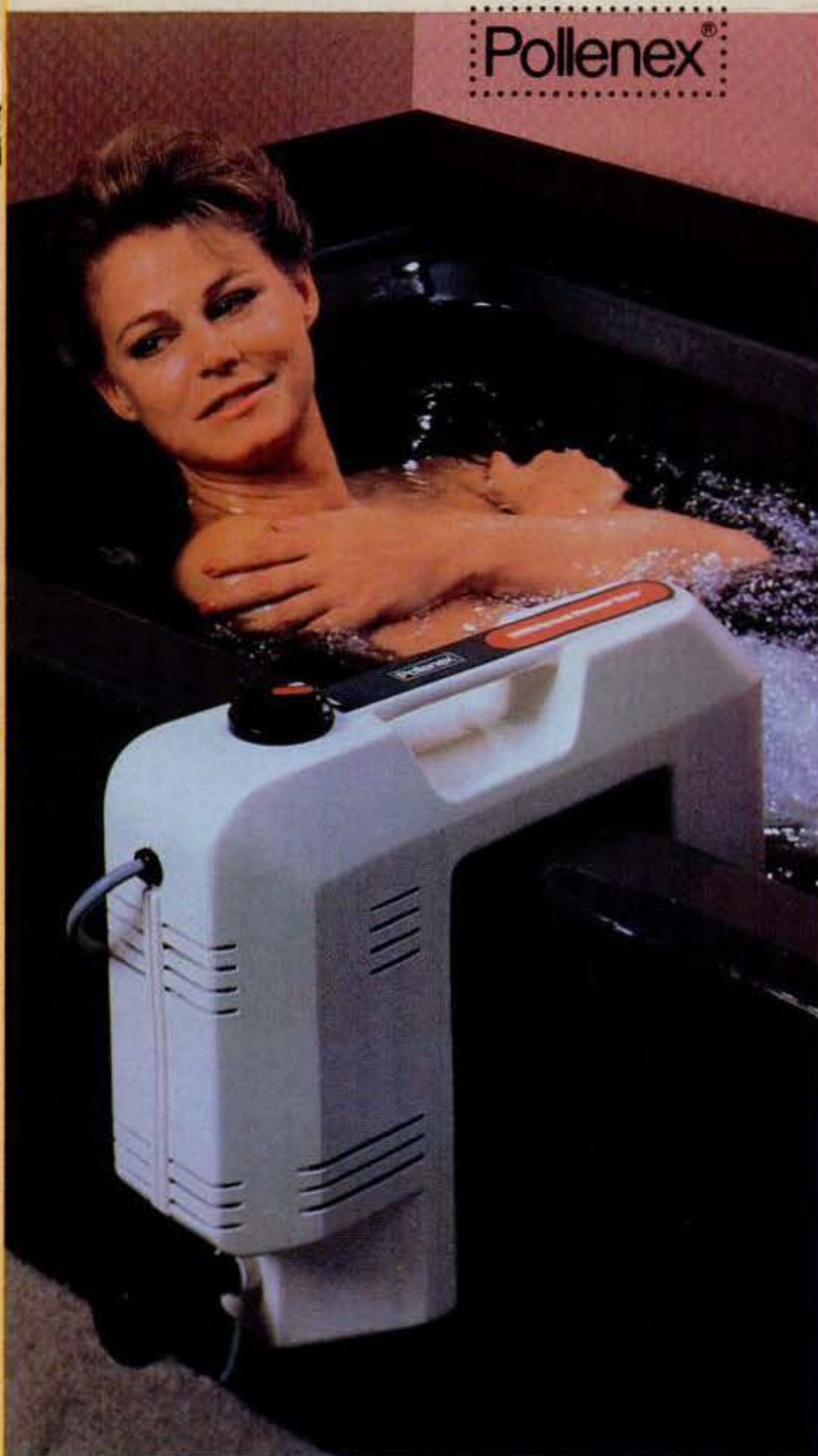
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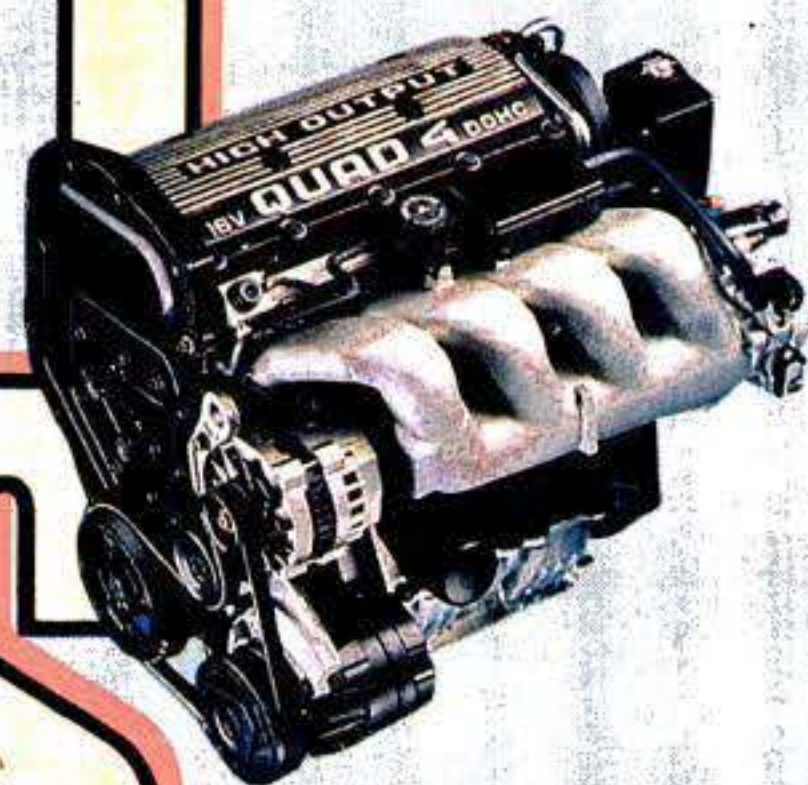
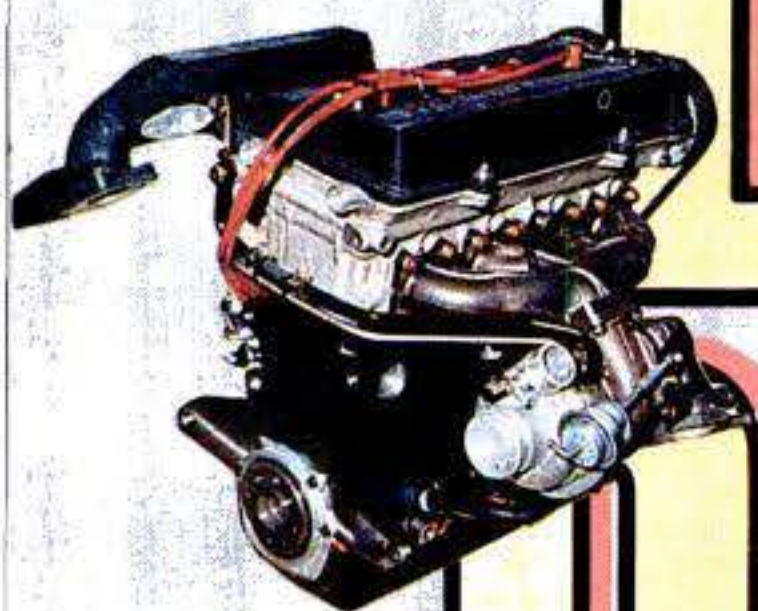
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DETROIT POWERS INTO '89



The 1989 model year promises to be the year of the high-horsepower engine. A fusion of the best American, European, and Japanese engineering launches some of the quickest cars Motor City has produced since the '60s—while, remarkably, meeting stringent fuel-efficiency and emissions standards. Although most of the big changes are under the hood, there are lots of other dazzling developments in this year's



automotive offerings. And the engineering innovations don't stop with cars. Small trucks boast their own, like exclusive engine designs, anti-lock brakes, and more. Share some of the surprises the POPULAR SCIENCE auto editors found as they drove the 1989 models from Detroit.

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On an empty Arizona highway, Chevrolet's new ZR1 Corvette pitched me past 60 mph with the ease of a wave tossing a bottle on a beach. A few seconds later the speedometer passed three digits, and the Corvette still was barely halfway to its limit. It was the kind of speed that you only expect from a flat-out race car—even when you're already going fast it never seems to let up.

But this wasn't a race car. The ZR1 'Vette was only the most spectacular of a series of neck-straining experi-

1960s. The ZR1 Corvette is in league with the fastest cars in the world, yet has an EPA rating of 25 mpg—sufficient to skim under the gas-guzzler penalty—and is certified to meet all current emission-control laws, which were nonexistent in the '60s.

But the ZR1 Corvette was only the first of a string of surprises as *POPULAR SCIENCE* drove the full lineup of 1989 models from Detroit. At Elkhart Lake, Wis., the first domestic 16-valve V6 in Ford's new SHO Taurus pushed it into the same ring as the Ford GT Mustang—destroying myths about the limitations of front-wheel drive. At Riverside, Calif., the test team drove

stock 5.7-liter Corvette V8, but the engine design is more from a kind of fifth dimension between the stock small block and Chevy's Indy-winning race engine.

The engine is mainly the product of GM's Group Lotus Division and is being manufactured by Mercury Marine in Stillwater, Okla., which would seem to ensure that a seafaring version is already in the works for the "Miami Vice" boat makers to play with.

Exact power output was still undetermined as *POPULAR SCIENCE* went to press, mainly because final, certified tests hadn't been completed. But pre-

HORSE

Performance records are being broken by new engines coming from Detroit in 1989. This time technology allows top performance without guzzling gas.

By DAN McCOSH
Detroit Editor

ences stemming from a fast tour with the new '89 models from Detroit. An amalgam of technology inspired by the best of European and Japanese engineering has turned out some of the fastest cars Detroit has produced in two decades, and I was left with the feeling that I was witnessing the beginning of a new horsepower race that's likely to continue into the next decade—or at least until another gas crunch looms.

In a style-conscious industry, it's unusual that the big changes this year are mainly under the hood. For the first time in recent memory, Detroit is introducing more new engines and transmissions than all-new cars. It's speed partly tempered with sensibility. The remarkable thing about this muscle-car revival is that it comes with far less penalty at the gas pumps than burning rubber drew in the late

two new turbocharged Pontiacs, including a resurrection of the engine that powered the turbocharged Grand National Buick Regal—the quickest domestic car until it was dropped from the Buick lineup last year. And as if anything more was needed to bring the ghost of the muscle-car era back to center stage, even Chrysler's middle-of-the-road A-cars get a new 2.5-liter turbo this year.

As we traveled the new-car circuit with our test equipment, finding single-digit 0-to-60 times common as bugs on the windshield, the story that emerged wasn't just raw horsepower, but a change in Detroit's thinking about where the ponies ought to come from, and where it should take the car.

The most extreme example was Chevrolet's new aluminum behemoth, simply called LT5. The bore centers and 5.7-liter displacement match the

liminary estimates range between 380 and 400 horsepower with torque at 400 pound-feet, compared with the 240 hp with base mufflers of the stock 5.7-liter Corvette block.

Crammed under the hood, the LT5 engine has the appearance of a slightly nicked solid block of aluminum. The installation is so dense it looks as if a bucket of water tossed on top would take a couple of minutes to wet the ground underneath. Manifolding, exhaust headers, and the rest of the necessary plumbing are packed as tightly as the tentacles of a dead squid, and in a couple of places the pipes are flattened as if someone had given them a hard kick to fit them in place.

As it turns out, the well-corseted look of the engine reflects the major design constraint. Chevy wasn't willing to alter the stock Corvette chassis radically, and the engine had to

fit up through the frame rails of the existing car—a neat trick with dual overhead cams and the 16-valve-per-cylinder head widening the cross section of the engine.

The squeeze play was accomplished with the piston centers in the same spot as the stock engine, but with a slightly lengthened stroke and an undersize bore. Also helping to compress the engine, the cast-aluminum cylinders are independent of the block and heads, with the exterior of the cylinder liners machined closely, minimizing the space between the liners.

"It was like unraveling a tangled ball of wool," is how Tony Rudd, Lotus

chief of research, describes the lengthy process that led to the final design. Proposed but discarded early in the game were a turbo V6, a multi-valve head modification of the stock 5.7 liter, and a twin-turbo stock 5.7 liter. None met the basic requirements for fuel efficiency, smoothness, or horsepower.

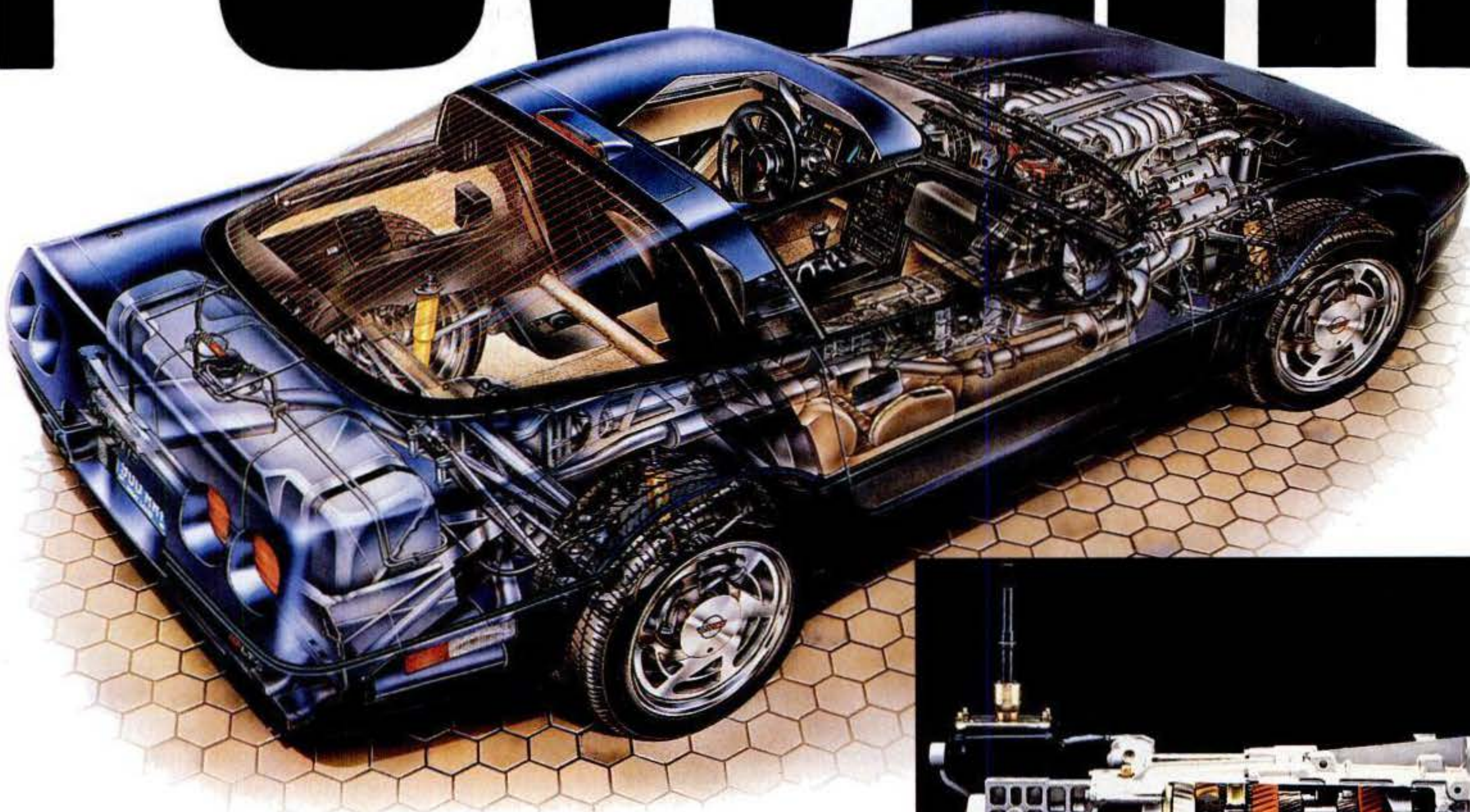
The clean-sheet-of-paper approach finally adopted called for an unusual construction using separate aluminum piston liners clamped between the block and cylinder head. Narrow angle valves allow dual overhead cams on each cylinder bank—making the LT5 one of the few production V8s with that type of arrangement.

The source of LT5's power is the standard trilogy of compression ratio, free breathing, and high rpm. Its 11.25-to-1 compression ratio is high enough that you might expect it to knock like a wayward husband at the door after closing time. But the ZR1 Corvette runs comfortably on regular unleaded gas, although premium is recommended.

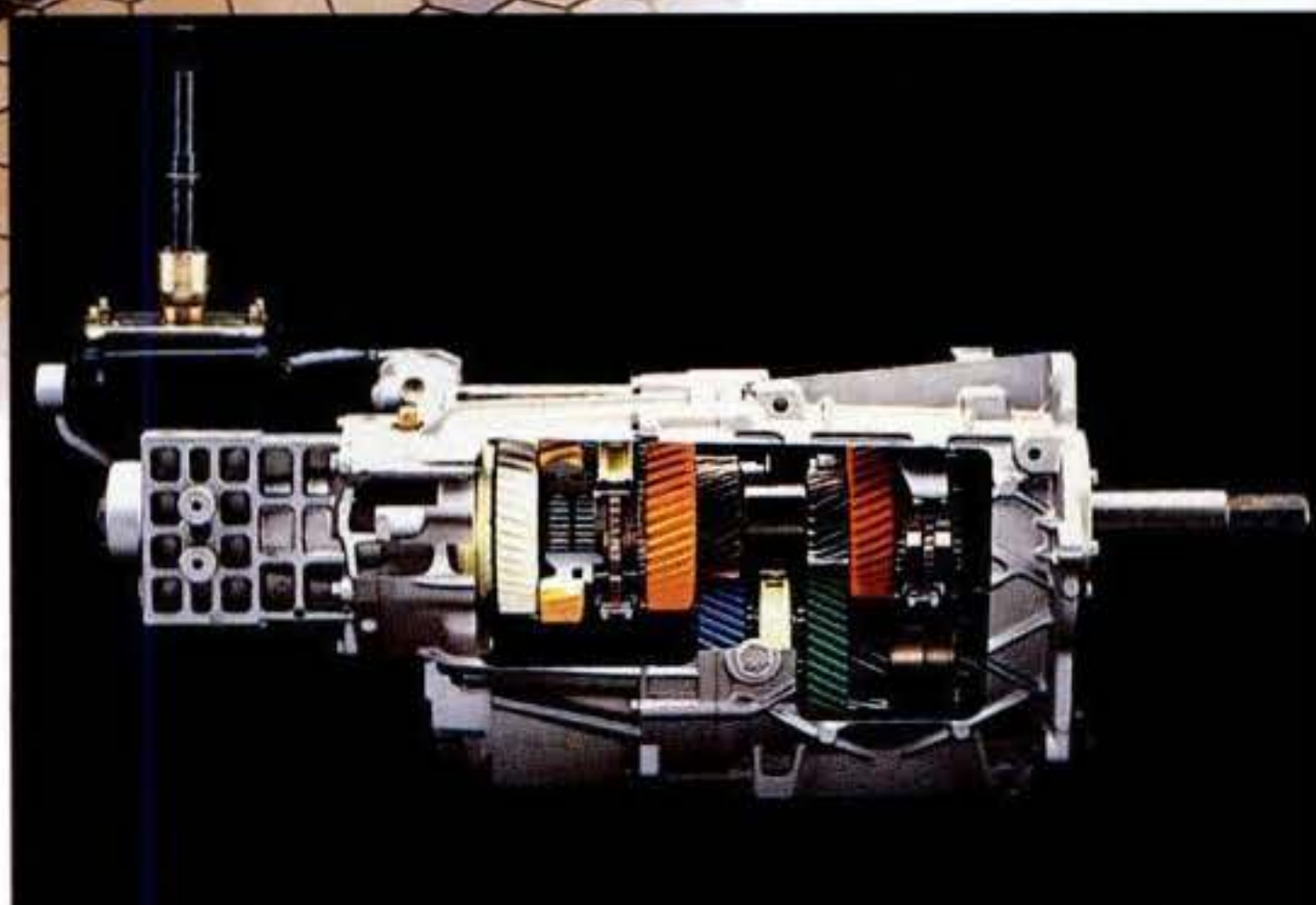
Rudd says that this feat of combustion control is achieved partly by the design of the clover-leaf-shaped combustion chamber. Also helping are the aluminum liners to help dissipate heat quickly.

Continued

POWER!



Special-edition Corvette ZR1 (above) mates a potent Lotus-developed 32-valve V8 engine with a computer-controlled six-speed manual gearbox (right) that provides neck-wrenching fun. At all-out acceleration, all six closely spaced gears are used; in city traffic the shifter skips second (shown in orange) and third (red) gears for economy and convenience.



The air induction is through an intricate manifold system that feeds air to the doubled intake valves in three stages. First, a

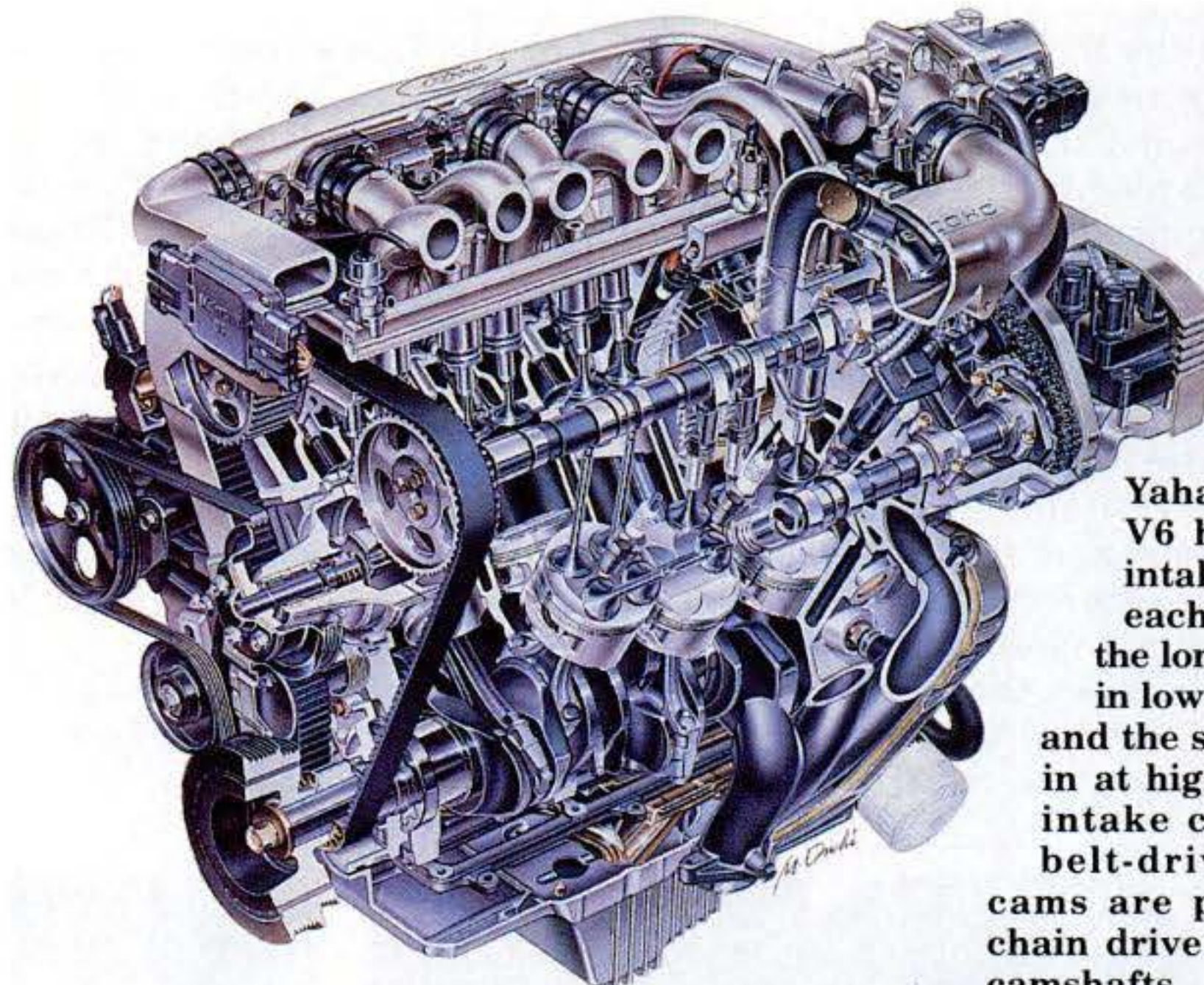
tiny nickel-sized throttle opens to run the engine up to about 35 hp. A harder stab at the gas pedal opens the first of two ducts big enough to swallow a tennis ball. Above 3,500 rpm another equally large throttle opens, and the engine is in full song up to a 7,500-rpm redline. The secondary intake operates off a separate runner that aims the airflow at the second intake valve, which operates at slightly different timing than the first.

Pedal-stomping override

Worried about parking garage attendants and "le'me-have-the-car" teenagers, Chevy incorporates a computer restriction that requires a special key to be used before the secondary manifold will operate. Without it, the ZR1 is tame and docile; with it, the sky's the limit.

My brief ride in a ZR1 was a short teaser without instruments aboard, just enough to confirm that Chevy achieved its goal of making this car fast enough to scare you. Even more impressive: It idles like a lamb and pulls strongly at low rpm.

The engine is coupled to a new six-



Yamaha-built SHO V6 has two tuned intake runners for each cylinder (top): the long one operates in low engine speeds, and the short one kicks in at high rpm. Its two intake camshafts are belt-driven; exhaust cams are powered by a chain drive off the intake camshafts.

speed West German-built ZF manual transmission. The new gearbox makes fingertip shifts effortlessly, with only enough mechanical feel to make engagement positive. The top two speeds are fuel-saving overdrive ratios.

The new transmission is also offered on "base"-level Corvettes in 1989. But as smooth as it is, I ended up being tripped up by one design feature intended to help increase measured fuel economy. When you start from a stoplight with just a light touch on the throttle, a computerized gate routes the shift lever directly into fourth gear from first. The one-to-four shift is annoying, and frequently makes for a stumbling shift pattern below 30 mph. But Chevy says it's needed to allow the six-speed and the big engine to slip past the 22.5-mpg minimum for "gas guzzlers."

From the extreme high output of the Corvette, it was almost a relief to jump into Ford's new SHO Taurus, a car that is simply fast but doesn't try to scare you. Not that the SHO is without moments of greatness.

The SHO V6 project originally was supposed to be a set of aluminum 16-valve heads bolted to Ford's three-liter V6. But like the Corvette project, an all-new design won out. The low-volume project was turned over to Yamaha Motor Co. Ltd.

The engine that resulted breaks new ground in several areas. Producing 220 hp at a conservative 6,200 rpm, and 211 lb.-ft. of torque at 4,800

rpm, the SHO V6 isn't in LTS territory, but it is one of the highest horsepower engines in a production front-drive domestic car. That means pushing the envelope of traction and handling for front-drivers, which tend to scrabble and rock on hard acceleration as weight is transferred to the undriven rear wheels.

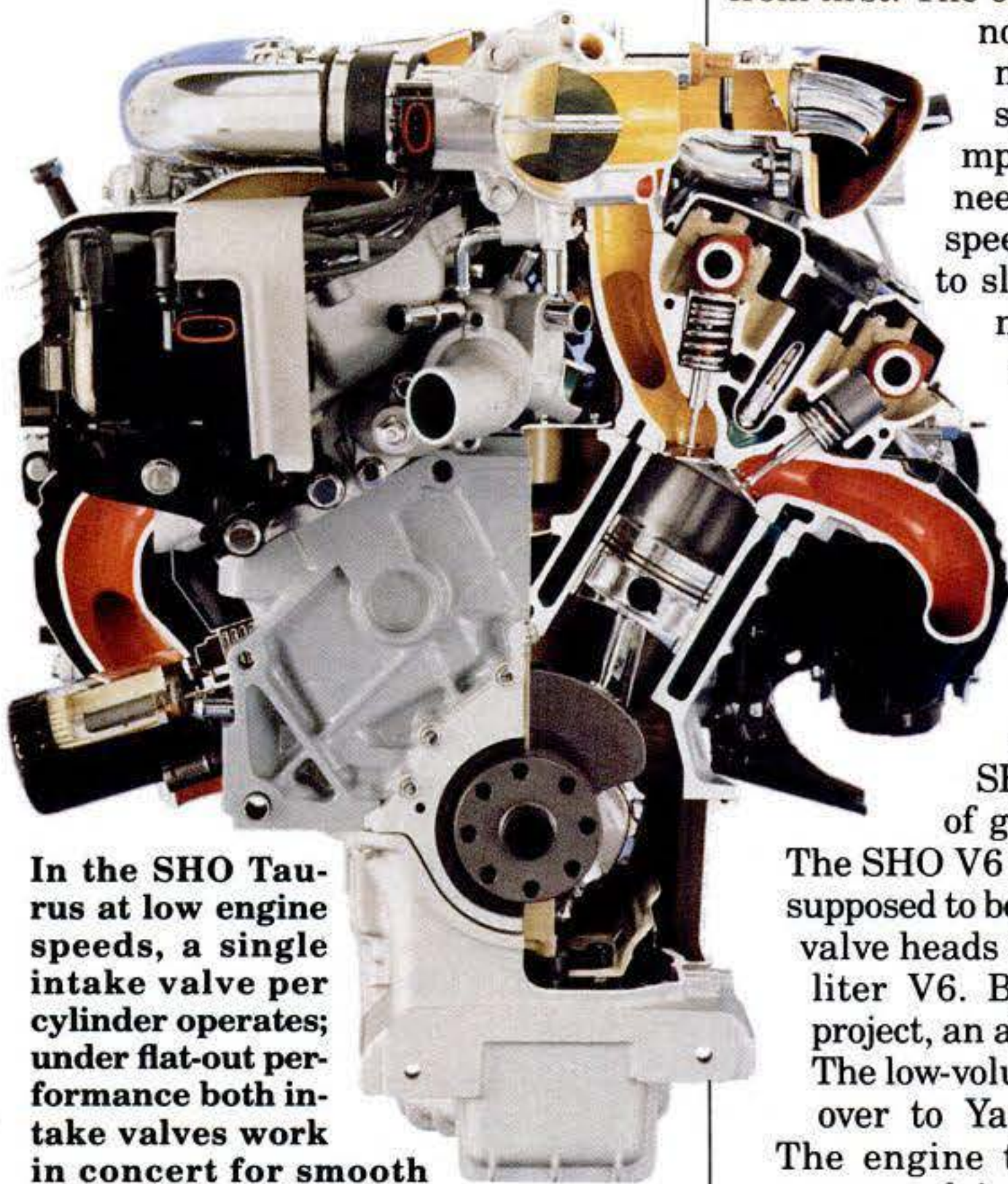
Strong performance

We strapped on the POPULAR SCIENCE fifth wheel and clocked 0-to-60 times of seven seconds, a figure that compares with the 6.8-second 0-to-60 time we recorded for the Mustang GT in an earlier test. Ford engineers told me that the SHO may, in fact, have an edge over the Mustang in some speed ranges.

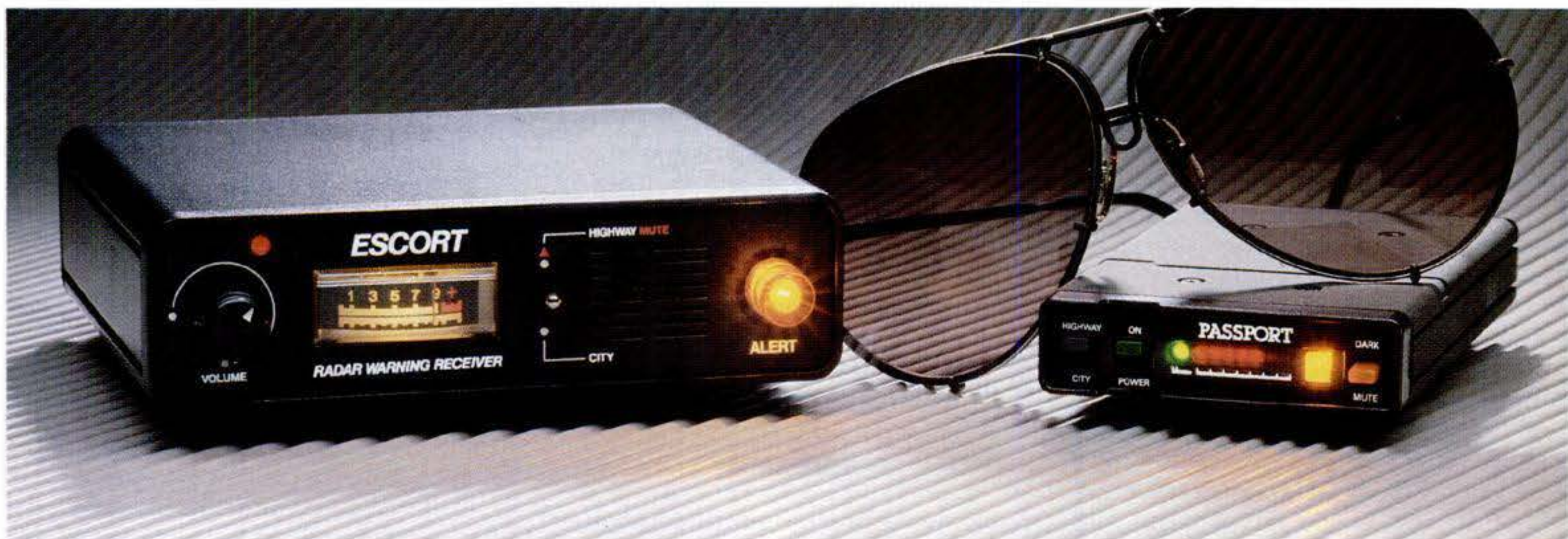
The SHO also presses some bona fide racing engines with its 74-hp-per-liter output, compared with 45 per liter for the cast-iron five-liter V8 in the Mustang GT. The SHO Taurus may well have the highest rating for a domestic production car.

One of Yamaha's specialties is thin-wall casting, a technique that shows up in the SHO engine's block and head design. An intricate casting technique is also required to make the intake manifold. Ford's Taurus is less stingy with under-hood space than the Corvette, allowing two tuned intake runners per cylinder—a dozen looping tubes that drape over the top of the block like a melted candelabra. There is a long one and a short one for each piston, each tuned to a separate rpm range. Each runner joins at a cross-over opening before leading the air into the cylinders. A secondary throttle plate reroutes air based on engine rpm—shifting to the shorter tube at about 4,500 rpm.

Continued



In the SHO Taurus at low engine speeds, a single intake valve per cylinder operates; under flat-out performance both intake valves work in concert for smooth power all through the range. The secondary throttle plate (top center) opens at 4,000 rpm to let all 24 valves breathe.



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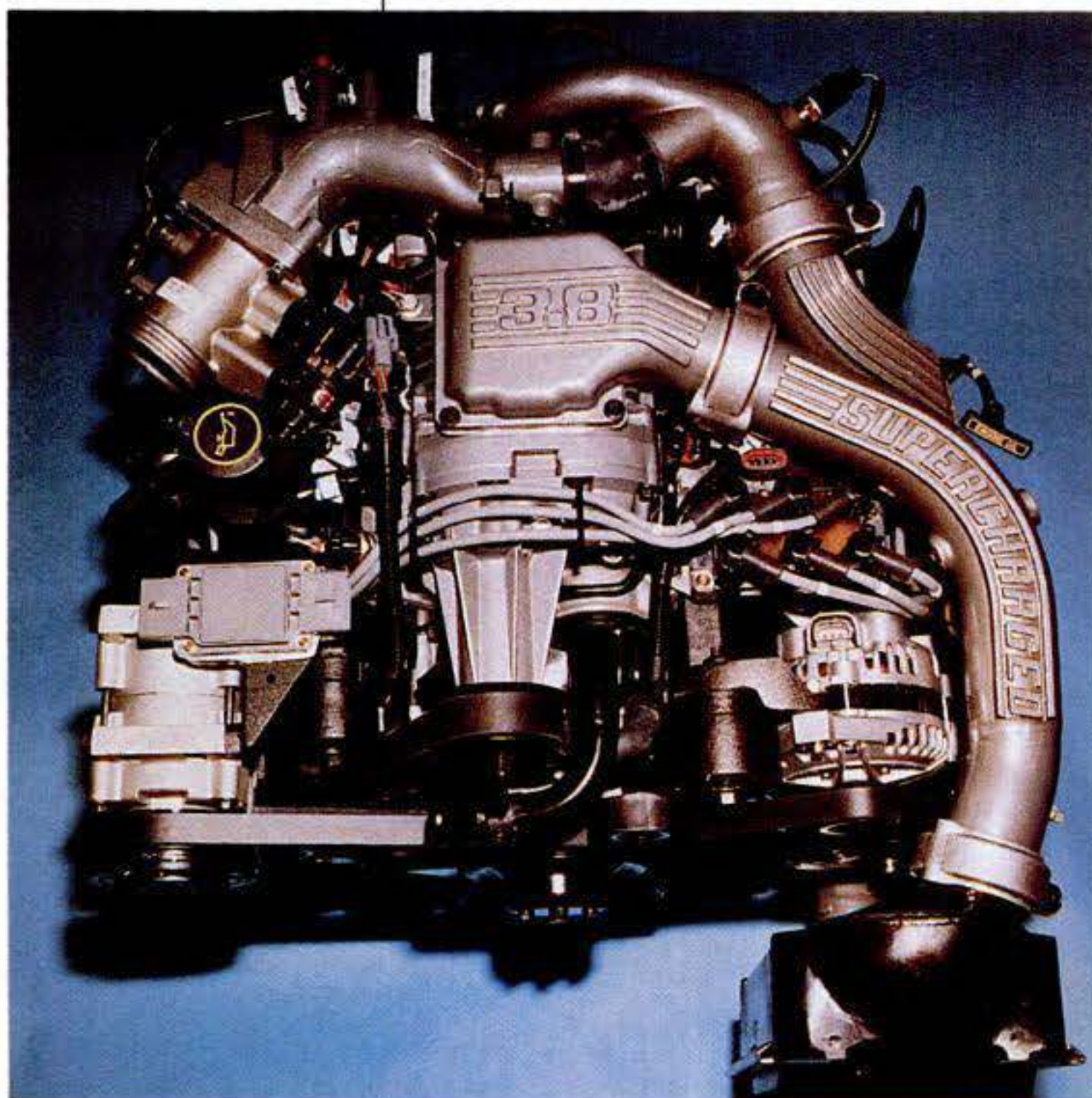
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DETROIT POWERS INTO '89

To handle the power, Ford stiffened up the SHO suspension, eliminating all but a trace of the base Taurus understeer—one of those

happy changes that improves handling without excessive harshness. Only a five-speed manual gearbox is available at the moment, which could restrict interest in the SHO package. But my quick impression of the SHO package is that it is likely to give high-priced German luxury-sedan makers fits—because comparable performance with an accent starts at nearly double the SHO Taurus's projected \$20,000 price.

Eaton supercharger (center belt-driven component) draws air through its inter-cooler (lower left) and long neck to boost Superbird's 3.6-liter power plant to 210 hp with torque to spare. To take the stress of forced induction, the cylinder head, block, pistons, and crankshaft were strengthened.



If the SHO comes across as free-wheeling as last year's stockbrokers, Ford's other major engine project is borderline hulking. The first production supercharger ["Supercharging Is Back!" Jan. '87] seen in years is unveiled along with the all-new Thunderbird/Cougar models in 1989.

Supercharging differs from the widely accepted turbochargers in that it uses a belt-driven blower that marches in lock step with crankshaft speed, rather than waiting for a pinwheel to spin up in the engine's exhaust pipes. It's one of those old ideas that still works and offers the potential for superior bottom-end torque and much faster throttle response.

In contrast to the sleek sophistication of the SHO V6, the T-Bird's supercharger package, with its bulky intercooler, is something of a "Mad Max" plumbing job, nearly as dense as the Corvette's LT5 installation. In fact, the difficulty of packaging a belt-

driven supercharger is one of its main drawbacks. To get power from the crankshaft, a belt loops to a free-standing pulley, then a second belt runs up to the three-lobed supercharger.

But the results are worth the effort. A ride in the new Superbird demonstrated that throttle response was as solid as any big-block V8, and we clocked respectable 0-to-60 times of 7.3 seconds, impressive for the nearly 4,000-pound Thunderbird.

Despite the performance and throttle response of supercharging, exhaust-driven turbocharging remains the boost of choice for most of the high-output engines that we drove.

GM orphaned one of the best examples of the breed when Buick dropped the Grand National Regal last year. The turbocharged 3.8-liter V6 made the special-edition Regal a screamer at 245 hp. But the Grand National turbo resurfaces in 1989, powering a special 20th anniversary GTA Trans Am to 245 hp with 340 lb.-ft. of torque. At Riverside, we clocked 0-to-60 times of 6.3 seconds for the GTA turbo, the second-fastest car we drove at the '89 launch.

Pontiac demonstrated a turbocharged 3.1-liter V6 in the Grand Prix, boosting output to 205 hp and 220 lb.-ft. of torque. The engine pulled us to 60 mph in 8.3 seconds.

Other GM efforts were more subtle. The Allanté gets a new 4.5-liter V8, which raises power to 200 hp with 265 lb.-ft. of torque, compared with 170 hp and 235 lb.-ft. in the old 4.1 liter. The power boost is enhanced by

[Continued on page 48]

ADAPTIVE AUTOMATIC

If you ever mastered the art of double-clutching a non-synchronized manual transmission, you've grasped the basic principle behind Chrysler's new electronically controlled automatic A604 transmission.

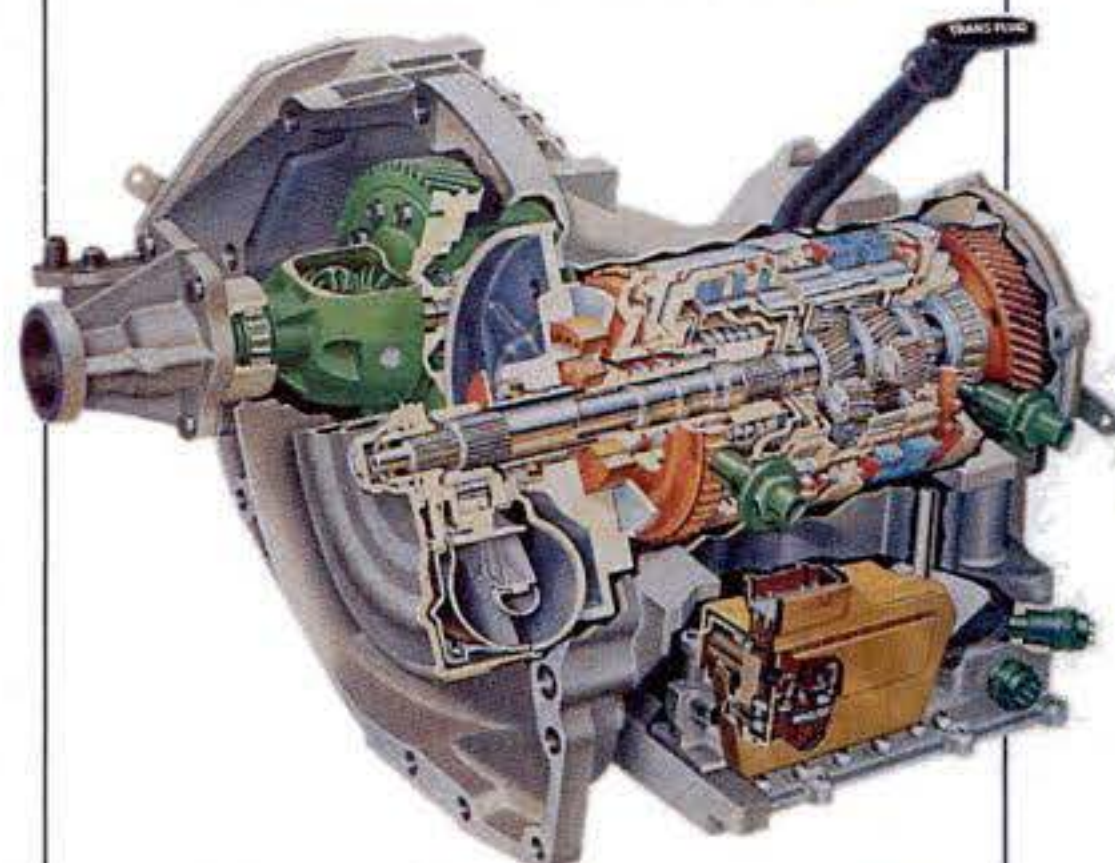
Just as matching speeds between the transmission's input and output shafts makes for a smooth shift, electronic sensors in the new Chrysler automatic precisely measure the speed of the input and output side of each planetary gear cluster. This information is fed into a control computer that actually adjusts the hydraulic pressure during the fraction of a second the shift is taking place.

Advances in electronic control technology make this feasible, and the result is a smoother shift than from the on-off controls in current electronic automatics.

Chrysler calls this an "adaptive" shift, and it makes for a distinctly less abrupt gear change than is offered either by a conventional hydraulically controlled automatic or the electronically controlled solenoid-shifted gearboxes currently available.

A test ride in a Dodge minivan equipped with the new A604 confirmed the smoothness of shifts. However, the difference was subtle, with other new automatics frequently shifting as well. The benefits should be more noticeable as the transmission ages, because any wear is automatically compensated for.

The new gearbox is shy about one-third of the parts in Chrysler's previous hydraulic automatic, which should add to its longevity as well. The lack of an over-running clutch means it can be towed with the wheels on the ground, and the added efficiency allows a slightly higher gear ratio that improves fuel economy.—D. M.



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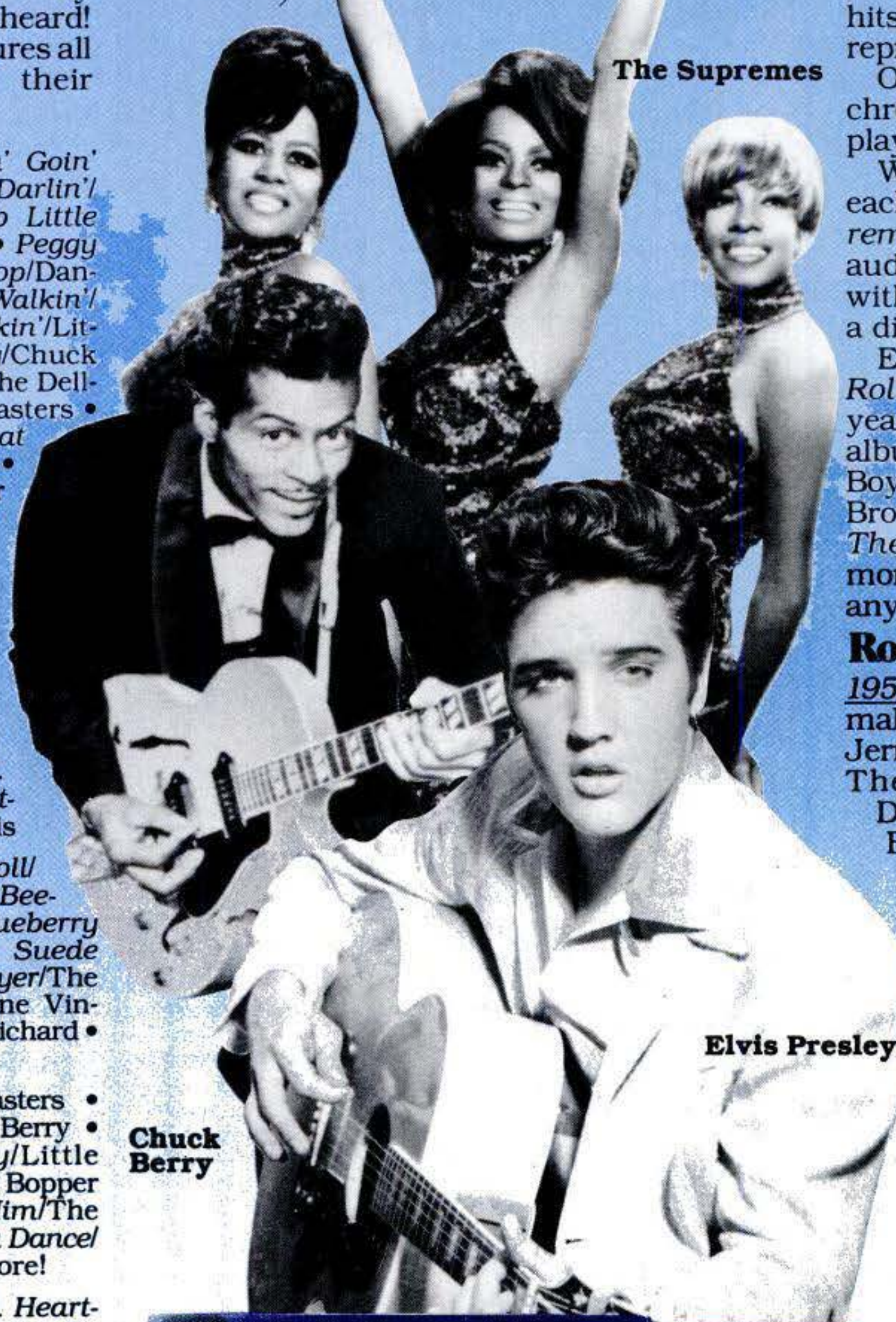
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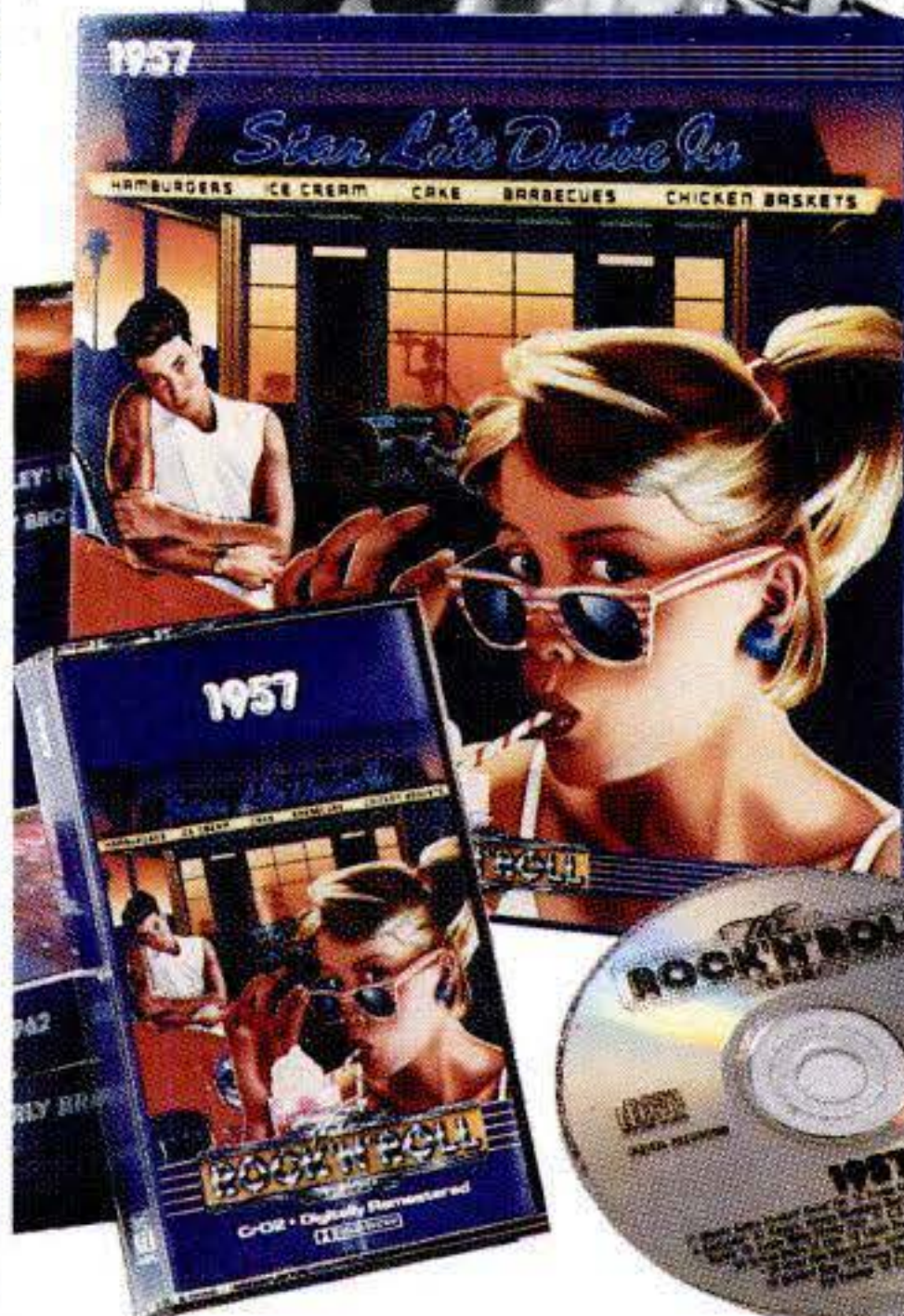
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Pop open the hood of a 1989 Ford Ranger pickup truck, and you immediately spot the familiar twin spark-plug banks reminiscent of a powerful V8. But wait—this engine looks awfully small, and there's only one valve cover on top of the engine block. While it does have eight spark plugs, the in-line four is not quite the muscle-bound V8 it appears to be.

Peering over the pickup's grille, Ken Klostermeyer, overhead-cam engine

design supervisor at Ford Motor Co., explains: "It's the redesigned 2.3-liter engine that fires two spark plugs in each cylinder to squeeze every ounce of performance out of a gallon of gas. With two plugs in each cylinder, you get more complete combustion of the fuel." Klostermeyer hopes that, as far as small trucks go, two plugs are better than one.

Across the board, small trucks are no longer being treated like the younger siblings of an auto maker's car line, getting technology as hand-me-downs. In 1989, trucks will get extra power from exclusive innovative engine de-

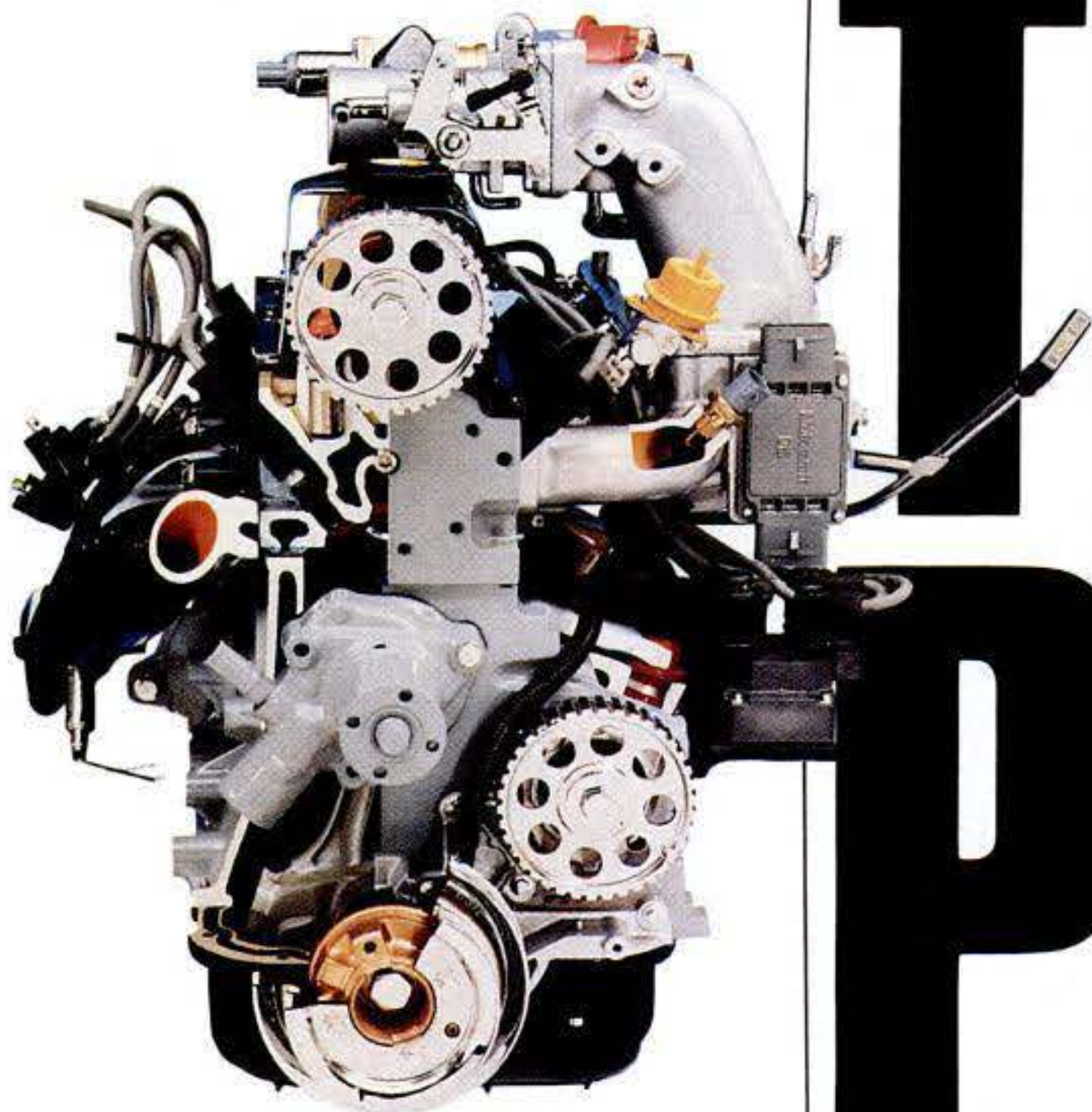
signs and increased availability of high-power off-the-shelf units, like the Chevrolet Vortec V6 and the Chrysler 5.2-liter V8. The Big Three will also equip small trucks with the rear-wheel anti-lock brake systems their big brothers already have. While no new styling cues come out of Detroit this year, Dodge will put out two limited-edition Dakota-based trucks: a sun-worshiper convertible and a high-performance pickup from Carroll Shelby.

Ford's 2.3-liter four-cylinder engine, long a mainstay for the Ranger, in-

Continued

Ford's new dual-plug 2.3-liter engine leads the technical innovations in small trucks for 1989. It's claimed to increase performance without sacrificing fuel economy. Dodge offers new specialty versions of its Dakota line, and Chevrolet adds power to the S-10 platform by increasing availability of its Vortec V6 power plant.

By BRIAN NADEL



Ford's overhead-cam 2.3-liter Ranger engine (above) squeezes a pair of plugs into each cylinder to improve combustion and boost power. First appearing in the 1989 Ranger (right), the engine gives crisp performance over highway or hill, and the addition of rear-wheel ABS helps to make smooth, safe stops when the pickup is unloaded.

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Gene J. Stroner,
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DETROIT POWERS INTO '89

corporates an extra bank of spark plugs on the intake side of the manifold, opposite the original four.

By engineering eight plugs into the engine's four cylinders, power was boosted by 16 percent to 104 horsepower at 4,750 rpm, and torque by three percent to 134 pound-feet at 2,750 rpm over last year's engine. This increased power does not come at the expense of fuel economy, despite the truck weighing 90 pounds more than the 1988 model.

Removing the valve shrouds from the engine made it breathe easier. The shrouds forced the fuel and air into an efficiency-enhancing turbulent swirl in the cylinder, but the price was restricted airflow and poor performance. New computer-designed intake ports are shaped to form equivalent turbulent swirls before the fuel-air mixture enters the cylinder.

A distributorless ignition system with a crankshaft-mounted pulse wheel simultaneously fires each pair of plugs. "As the wheel rotates through a sensor, it sets up an electrical signal that goes to the engine-control

computer, which tells the ignition system when to fire," says Klostermeyer.

For those who want pep, Chevrolet plans greater availability of its 4.3-liter Vortec V6 engine. S-10 and Blazer will offer the option of the 90-degree V6 design for 1989, and it will be standard on the Astro minivan.

Rated at 160 horsepower at 4,000 rpm and 230 lb.-ft. of torque at 2,800 rpm, the Vortec cuts the truck's 0-to-60 time to about 10 seconds, a two-second improvement over last year's 92-hp model.

For truck buyers who feel the need for a scorching sub-10-second acceleration time, a 5.2-liter V8-powered mid-size truck comes from an unlikely source: Carroll Shelby, of track-tuned Cobra fame. In the latest project from his Whittier, Calif., workshop, 175 horses are stuffed under the hood of the Dodge Dakota. An '88 prototype with a three-speed automatic transmission achieved a 9.2-second 0-to-60 acceleration run. The '89 production version will be equipped with a four-speed automatic transmission.

While the Shelby crew considered a convertible version, they are leaving a tanning model to Dodge's association with ASC Inc. of Southgate, Mich. Bruce Benedict, planning chief for the Dakota line says, "We plan to take the top off of a couple of thousand Dakotas and replace the sheet-metal roof with a padded roll bar and a fold-over

vinyl top." Benedict claims it will be priced to compete with convertible cars, with availability on the West Coast around spring; later on the East Coast.

The Big Three are now extending rear-wheel anti-lock brake systems to small trucks. Chevrolet S-10s, Blazers, and Astro minivans will join the Chevy C/K full-size pickup in having this safety feature as standard equipment. Dodge Rams and Dakotas, as well Ford Rangers, also get rear-wheel ABS. The truck systems sense wheel lockup ["Pick of the Pickups," June '87] and pulse brake fluid to the rear pads. This pumping action modulates brake-fluid pressure, keeping an emergency braking situation just short of a dangerous skid to improve stopping.

I drove the '89 Ranger and found it consistently stopped smoothly and straight, whether the road was black-top or loose dirt on washboard. In particular, the brakes reduced the side-to-side sway common when hard-braking an unloaded pickup.

However, these systems only modulate the rear brakes, and work only in the two-wheel-drive mode. For 1989 the Jeep Cherokee and Wagoneer get a Bendix-designed ABS that operates on all four wheels and in either drive mode. The system has electromagnetic sensors at each wheel; it pulses brake fluid to each front independently, but to the rears, as a pair.

This appears to be only the first act of the truck technology play. GM reportedly is putting together a plastic-



Geo Tracker (above), GM's newest sport-utility vehicle, is built in Canada by Suzuki. With coil-spring suspension on its 88.6-in. wheelbase and an 80-hp engine, it should attract potential Samurai buyers interested in a smoother ride. Right: Built on the same wheelbase as the standard Aerostar, the extended version is 15-in. longer, with room for 20 percent more cargo or more leg-, elbow-, and head-room for the back-seat passengers. Below: When the sun comes out, the ASC/Dodge convertible truck shines. If it rains, cover up with its fold-over vinyl roof.

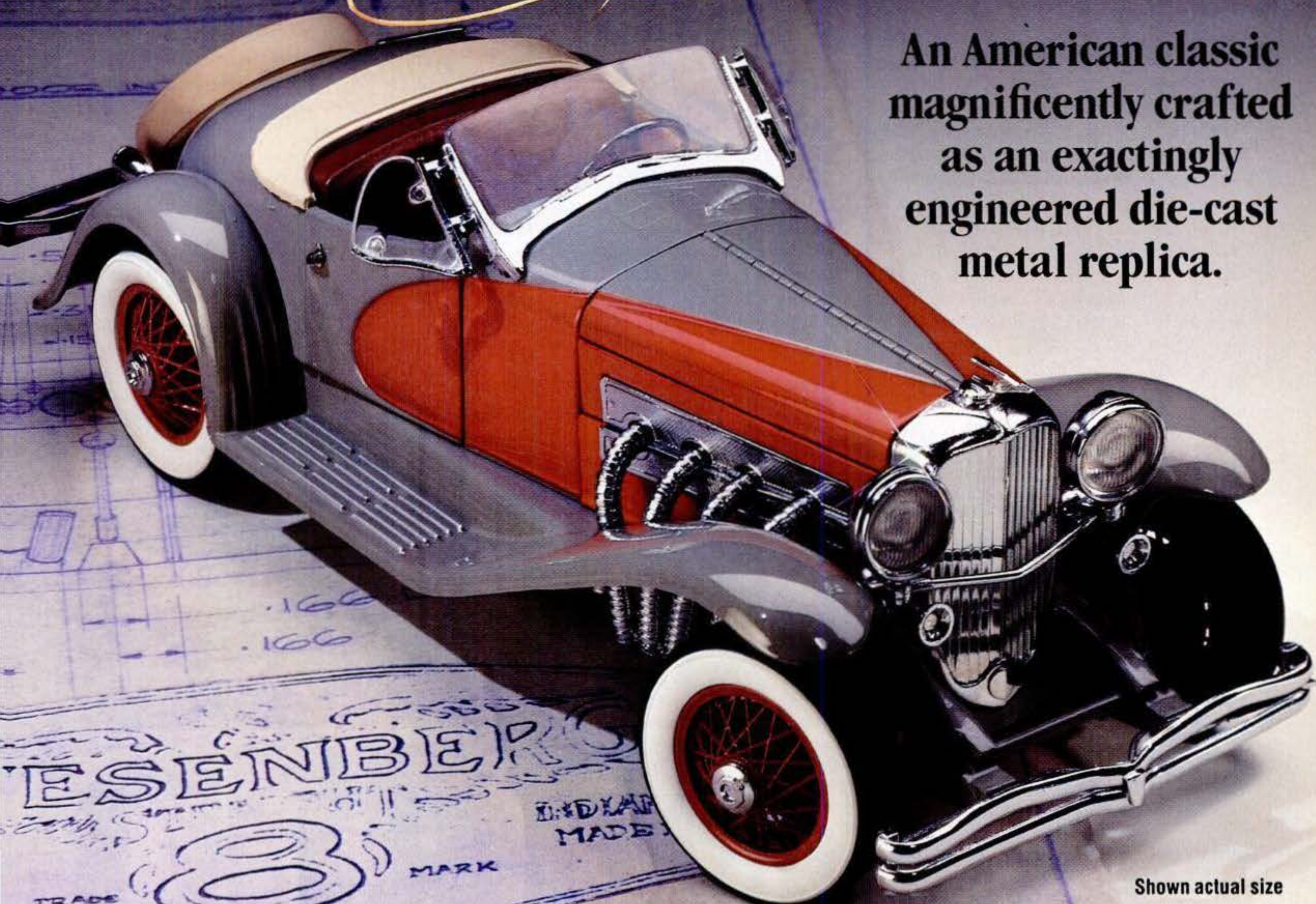


body pickup bolted onto a Fiero-type space-frame. Chrysler is said to have a new family of light truck engines in the works; and Ford's better idea looks like a family-size four-door Bronco for next year. One of the first of these futuristic truck concepts to make it to prototype testing is GM's Sierra A/R 400, which rides on a Lotus-based active suspension. The next decade is shaping up to be one of exciting developments and fresh engineering ideas.

P 5

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Both the engine and the undercarriage are authentically recreated and, of course, the doors and both sides of the hood open.

Each component of this model is individually inspected, then hand-assembled. Note the gleam of the model's finish. It is achieved by polishing each piece of metal, then hand-spraying the paint finish. Finally, and perhaps most remarkably, each car is actually hand-waxed.

Surprisingly modest price.

The Duesenberg SSJ is the stuff of dreams—but the original issue price of this Duesenberg SSJ replica is only \$88.50, payable in three monthly installments of just \$29.50 each. This is an exclusive commission available only by direct subscription from the Danbury Mint; it is not available in any store.

Satisfaction guaranteed.

To reserve a Duesenberg SSJ in your name, you need send no money now. You will be billed in three convenient monthly installments, your first in advance of shipment. If you prefer, you may charge each monthly installment to your VISA or MasterCard account.

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DETROIT POWERS INTO '89

If you are planning a pilgrimage to auto row in search of new-car excitement, buckle your seat belt good and tight and get ready: 1989 is shaping up as the year of the high-powered, graceful performance car.

Along with the year's only all-new vehicle, the Ford Thunderbird, there are a broad assortment of detail and styling changes and several innovative engineering advancements in store. From Ford's twin powerhouses—the supercharged Thunderbird and the SHO Taurus—to the ZR1 Corvette, the battle for who's king of the horsepower hill is already on. The styling

studios have been working overtime to package this new-found zest for speed with longer, sleeker bodies that slice through the wind with a minimum of effort.

While this insider's preview of the '89 cars concentrates on engineering advances in *domestic* models, the distinction is now especially difficult to make. After years of kicking and scratching, Detroit has finally adopted international attitudes and standards, and it is now a global business. The Big Three shop the world for both components and complete vehicles for sale in their own dealerships. More than ever, the inspiration for any given model—both its engineering and styling—is just as likely to come from

Europe or Asia as from southeast Michigan. Even if a car is stamped Made in America, it may well contain a Japanese engine, German transmission, or even an Italian skin.

Detroit's overseas technology reach means that fewer American consumers will automatically turn to Honda or BMW for up-to-the-minute design and engineering features. These domestic autos are now ready to compete on an equal basis with the best the world has to offer.

Ford: winner again

Ford Motor Co. now leads both General Motors and Chrysler in the ability to field contemporary automobiles in

Continued

This model year may be seen as the beginning of the internationalization of Detroit, with the Big Three going offshore more than ever for new cars and components. Ford has teamed up with Yamaha to get a high-output V6; GM picks up a new 32-valve V8 from Lotus and starts the Geo brand for its Japanese-source cars; and Chrysler gets a revamped Colt line and three-liter V6s from Mitsubishi.

By **DON SHERMAN**
Special Projects Editor



DETROIT GOES GLOBAL



Top: For 1989, Riviera gets an extra 11 in. in the trunk and smoother styling in a return to the traditional "Riv" look. Thunderbird Super Coupe (above) turns heads as fast as it turns laps, as the fifth-wheel testing shows. Superbird's wings provide smooth and responsive handling with all-new control-arm suspensions front and rear.

HOW THE WORLD'S SLIPPERIEST SUBSTANCE* WILL MAKE YOUR NEW CAR ENGINE STAY NEWER AND YOUR OLD CAR RUN LONGER

With fall around the corner and a fleet of exciting new cars about to roll onto showroom floors, perhaps you'll be looking closely at those new '89 models. Or perhaps you are plenty happy with your old car and want to keep it running longer.

Why not give your new car a bright future or your old car a reprieve from life-shortening engine wear with a single-quart treatment of one of the most credentialed friction reducing and gas saving treatments available today: **Slick 50**, the one-time treatment that makes the slipperiest substance known to man*--"Poly"--bond to your engine's most vulnerable moving parts. *NOTE: The 1988 Guinness Book of World Records (pg. 182) says: "The lowest coefficient of static and dynamic friction of any solid is 0.02, in the case of Polytetrafluoroethylene - equivalent to wet ice on ice. It was first manufactured in quantity by E.I. duPont in 1943, and is marketed as Teflon™."

PUTTING "POLY" TO WORK

Slick 50's secret is "Poly"--that's polytetrafluoroethylene--the same miracle chemical that keeps Teflon™ pans from sticking. But "Poly" itself couldn't help your car engine--new or old--until PetroLan Corporation researchers discovered how to suspend Poly in motor oil in a way that made them fuse automatically to internal engine surfaces. The results are as logical as they are dramatic: a **simple one-quart treatment** reduces engine friction and operating temperature. And because it works from the very second you start your engine (during those critical oil-starved seconds of start-up, before full oil circulation) until the time you shut it off, your valves and pistons will begin saying "Thanks!" with higher gas mileage, horsepower, and longer engine life.

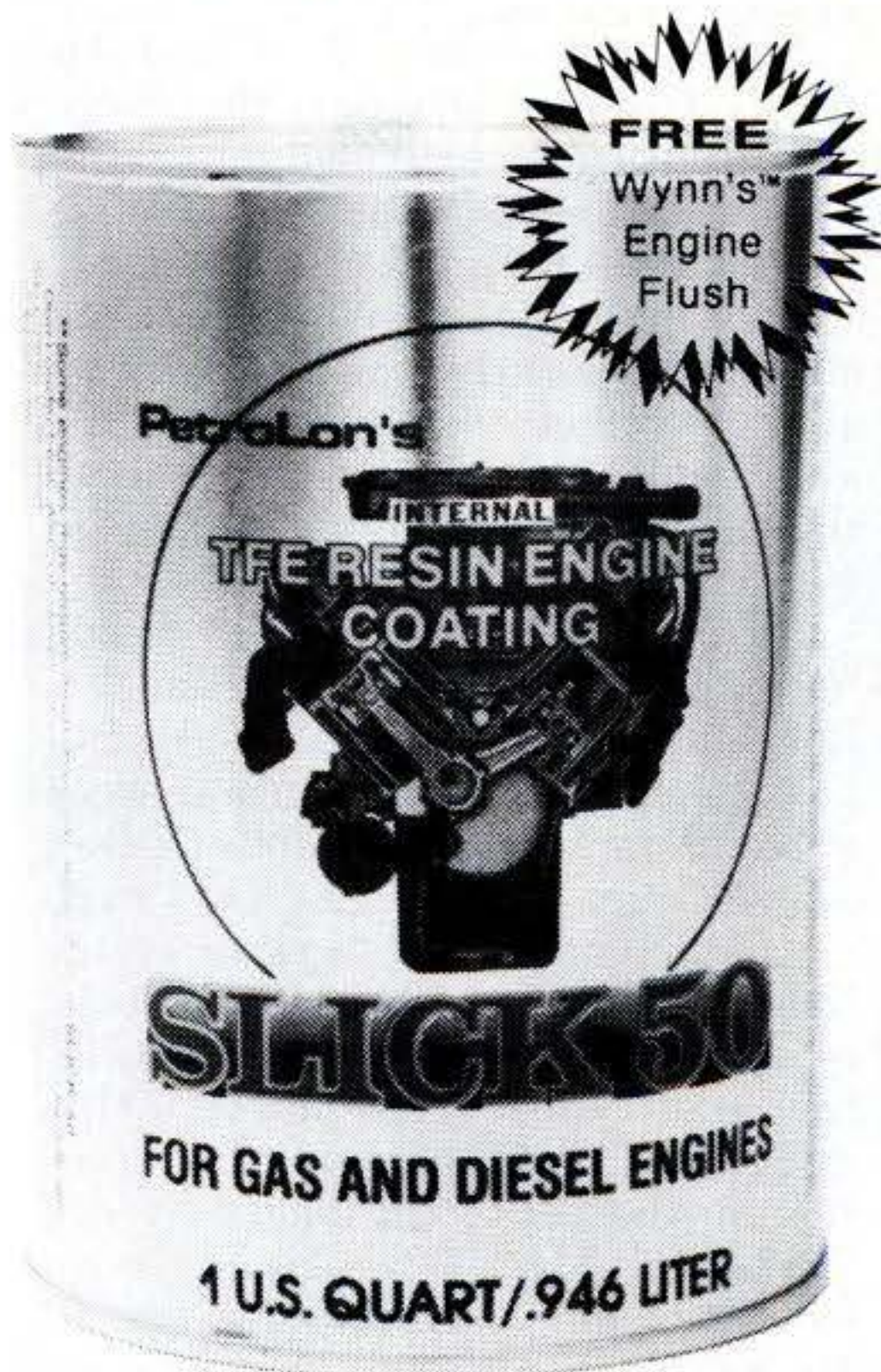
SKEPTICS SILENCED: ENDORSEMENTS BUILD

But don't just take our word for it. We're already sold on Slick 50. Listen to what some unbiased experts have had to say. Here's confirmation from the respected, independent journal **Consumers Digest**, in a March/April 1982 editorial feature: "Slick 50 does reduce engine heat and ordinary wear, and our informal tests indicate that it will improve gas mileage by about two or three miles per gallon...Slick 50 does exactly what PetroLan claims it does."

Independent tests carried out at universities and labs in both the United States and Europe have repeatedly borne out **Consumers Digest's** conclusions. And that's not to mention the rigorous **Federal Aviation Agency**. Mightily impressed by the results of intensive engine wear tests, the FAA granted its full acceptance to a similar product--Slick 50 Aircraft Treatment (F.A.R. #33.49)--and they're not easy folks to convince!

T.V. VIEWERS WATCH TORTURE TEST

Perhaps most dramatic of all was the torture test overseen by the **Automotive Services Council for Pennsylvania** and watched by thousands on **TV station**



WTVE. Three cars with between 75,000 and 129,000 miles on them were treated with Slick 50. Six months later the oil was completely drained. With oil plugs removed, the cars were driven for about half an hour. Not only did the water temperature not rise, but--thanks to Slick 50--the engines sustained no apparent damage!

SIMPLE 2-STEP TREATMENT

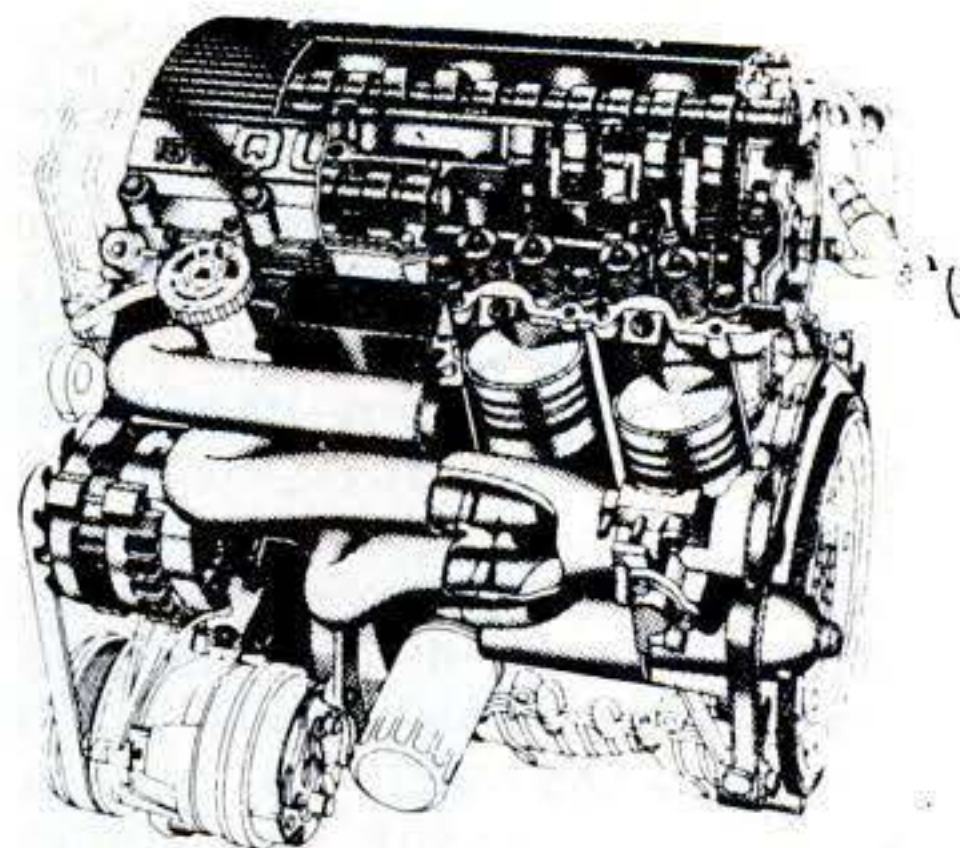
Whether you want to reap Slick 50's benefits for new car or old, we're making it easy for you. First, we'll send you Slick 50. Second, you'll also get a **free treatment of Wynn's™ renowned Engine Flush**. A few minutes before your next engine lube, clean out your motor by adding your free Wynn's flush and letting the engine idle for five minutes. Then drain the oil, change the filter and add fresh oil, substituting Slick 50 for the last quart (engines with oil capacities of seven quarts or more need two quarts). Leaving Slick 50 in the crankcase for 3000 miles is all it takes to bond Slick 50 permanently to any engine--including turbocharged, aluminum block, rotary or diesel engines. One treatment does it; **no need to keep on repeating during future oil changes.**

Slick 50 won't harm your engine or affect your new-car warranty: it's suspended in a high-grade petroleum oil (American Petroleum Institute service classification SF-CC-CD) that meets or exceeds all engine warranty requirements. And it'll work with all compatible synthetics as well.

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3. Lower engine operating temperature
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5. Boost your horsepower
6. Make your oil and engine last longer to help avoid costly overhauls
7. Help make up for lubrication losses from new unleaded gas
8. Provide a probable lubrication safety margin in the event of sudden oil pressure loss.



3. Lower engine operating temperature
4. Increase gas mileage
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DETROIT POWERS INTO '89

today's competitive market. In the early '80s, when GM was planning a reorganization and Chrysler teetered on the brink of

bankruptcy, Ford too faced dire straits with a rapidly aging product line. But rather than deal with the crisis with a stopgap, Ford management took the longer view, committing itself to an era of aerodynamically styled, highly functional automobiles. Moms and pops of America were presented with an LTD replacement that the competition labeled a "jelly bean," due to its rounded bodywork. To the competition's amazement, the public's tastes were more sophisticated than anyone—except some prescient Ford planners—had imagined.

Momentum generated by the Taurus in 1986, and since reinforced by the Lincoln Continental and the Ford Probe, will be bolstered further this fall with the new Ford Thunderbird and Mercury Cougar. While other auto makers are banking on front-wheel-drive cars powered by four-cylinder engines, the all-new T-Bird and Cougar use rear drive and hefty six-cylinder power plants.

The T-Bird and Cougar also fly in the face of reskinning new models out of existing platforms. Except for some carry-over in the engine and automa-

tic-transmission areas, they are clean-paper engineering efforts from tire patch to roof line.

Aimed at the heart of the mid-size specialty-coupe market, the silky-smooth T-Bird/Cougar is slightly lower, a bit wider, and more than three inches shorter than its immediate predecessor, but built on a wheelbase that was stretched by nearly nine inches. There are major increases in rear-seat hip and shoulder dimensions, and overall the new design is roughly 10 percent roomier than last year's model.

All models are powered by Ford's fuel-injection-equipped 3.8-liter V6. Base and luxury models have 140 horsepower transferred through a four-speed automatic transmission. Hotter T-Bird Super Coupe and Cougar XR-7 models use an upgraded version of the same V6 fitted with a belt-driven Roots-type supercharger and an air-to-air intercooler (see "Horsepower!" this issue). Last seen in domestic production on the 1964 Studebaker Avanti, the T-Bird's Roots-type blower gives a feeling of power on demand resembling a V8.

While GM and Chrysler have embraced front-wheel drive and strut-type suspensions practically across the board, the new Ford-Mercury models feature rear drive and independent control-arm-type suspension front and rear. This approach is more expensive

and results in a heavier car, but it offers undeniable handling benefits.

The front suspension design uses a long vertical knuckle connected to a short A-shaped upper control arm and a single transverse lower link. Longitudinal loads are fed into the front cross member through a double-isolated tension strut. Coil springs are concentric with nitrogen-gas-pressure shock absorbers.

The rear suspension has a large H-shaped lower arm that feeds most of the wheel loads into the unitized body through a rubber-isolated cross member. A curved upper control arm helps maintain proper rear-wheel camber, and a special toe link between the lower control arm and the subframe prevents the rear wheels from steering outward on heavy cornering loads or large bumps. As a result, the chassis can be tuned for near-neutral handling without any disturbing oversteer during emergency maneuvers. The final-drive unit is now fixed to a rear cross member instead of moving with the wheels. This clears space for a larger trunk and lets the gas tank be located farther forward.

The new independent suspensions comprise a wish list of engineering features:

- A five-fold increase in anti-dive geometry keeps the body level during hard braking.
- The turn circle was reduced by 5.6 feet despite the longer wheelbase.
- The front caster angle was increased from 2.0 to 6.5 degrees for better steering feel and stability.
- Major increases in wheel travel and variable-rate coil springs damped with gas-pressure shock absorbers, both front and rear, smooth the way.

The T-Bird Super Coupe and the Cougar XR-7 also get an automatic adjusting suspension that varies the shock valving between a soft and firm mode, depending on the vehicle's speed.

My early test drives revealed that the new T-Bird and Cougar are poised and confident on the road, but their acceleration performance is no great leap forward, even with the 210-hp en-

Continued



Metro (above), made by Suzuki, is the entry-level model for the new GM Geo brand. A three-cylinder engine powers this city coupe through traffic. Dodge Acclaim/Plymouth Spirit (right), based on the K-car chassis platform, is Chrysler's latest attempt to lure family-sedan buyers to its fold.



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DETROIT POWERS INTO '89

gine under the hood. The supercharged V6 responds immediately to a tap of the throttle, but this more sophisticated 1989 model is roughly 200 pounds heavier than the car it replaces.

The new T-Bird and Cougar are more likely to make friends when their handling and braking qualities are put to the test. The fat tires, variable-assist steering, control-arm-type suspensions, and optional anti-lock four-wheel disc brakes move these domestic models into a realm of sophistication that had been the exclusive domain of foreign

producers. The cars drive as well as they look, and their looks are truly world class.

While Ford spent most of its 1989 engineering budget on the T-Bird and Cougar, carry-over car lines have not been neglected. The SHO Taurus (for super high output) is clearly the sleeper of the season, and may steal some of the limelight from the new coupes. To add major amounts of horsepower to the eminently successful Taurus, Ford turned to the Japanese motorcycle expert Yamaha for an all-new engine. The details of this three-liter 24-valve double-overhead-cam V6 are outlined in "Horsepower!", but suffice

it to say that the SHO engine's 220 hp is a needed step up for this sedan. A Mazda-supplied five-speed transaxle handles the new engine's output, and the Taurus's front-drive suspension does a fine job of firmly transmitting the power to the pavement. Chassis upgrades include firmer suspension bushings, tighter shock-absorber valving, stiffer anti-roll bars, wide 15-inch wheels and tires, and a new four-wheel disc-brake system.

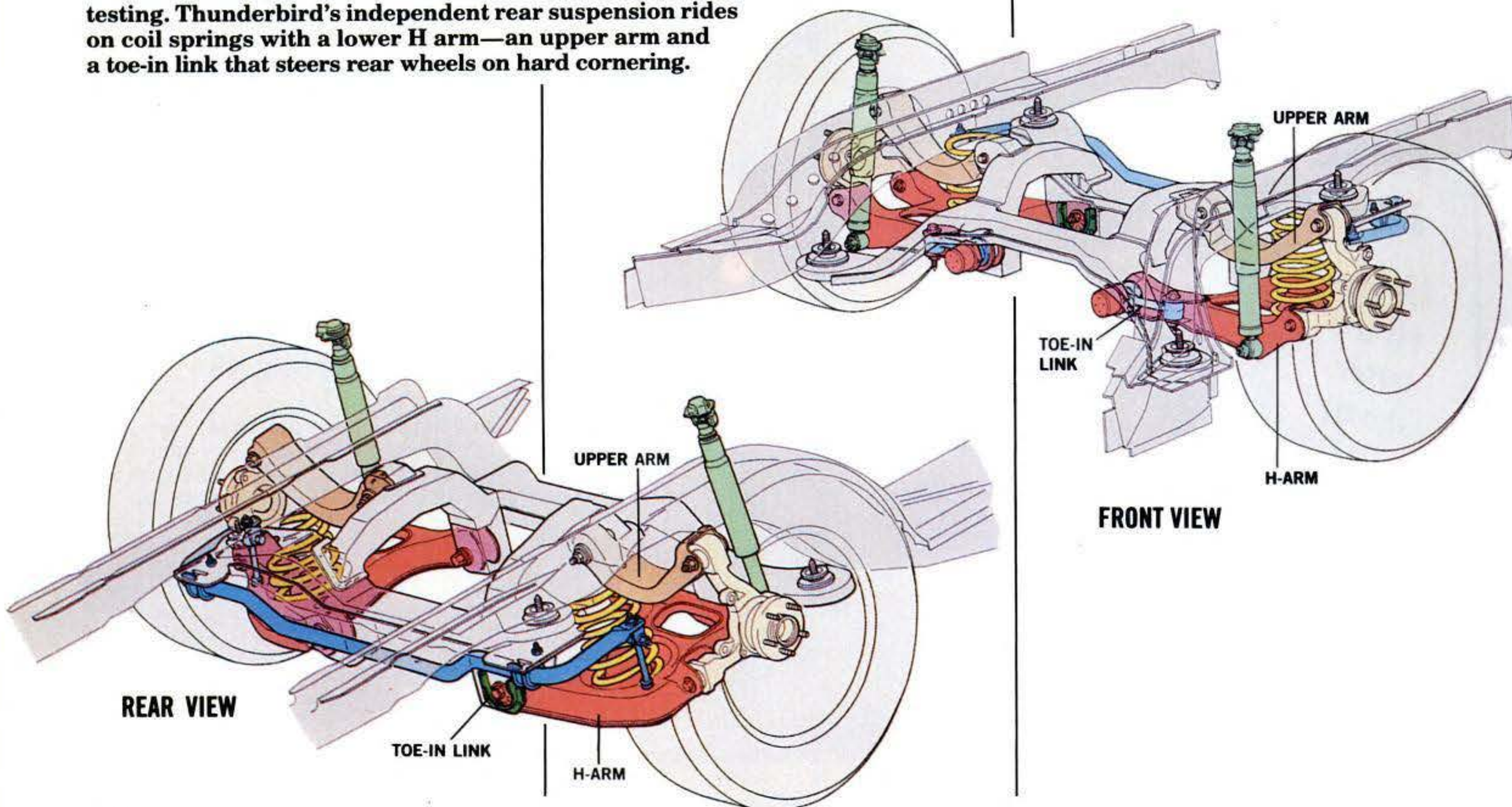
Other Ford changes for 1989 include a new brake system for Taurus and Sable. Many customers complained of poor brake-pedal feel, and POPULAR SCIENCE testing also revealed a lack of modulation during panic stops ["Luxury for Less," July]. Poor brake performance had been noted in earlier tests of Taurus and Sable as well [April and June '86]. The problem was traced to a front-brake caliper design wherein the brake pads rest a short distance from contact with the brake rotor to reduce drag and improve fuel economy. Under hard braking the front pads had first to move a small distance to make contact with the rotor before they could generate any significant stopping power. This upset front-rear braking balance, causing premature rear-brake locking and lackluster emergency-stopping performance.

The solution is practically a whole new brake system: a redesigned vacuum booster, a new master cylinder, and major changes in the front calipers. Preliminary evaluation of prototype models by POPULAR SCIENCE

Continued



The SHO Taurus (above) might steal a little thunder from the new T-Bird; it clocked some impressive laps during testing. Thunderbird's independent rear suspension rides on coil springs with a lower H arm—an upper arm and a toe-in link that steers rear wheels on hard cornering.



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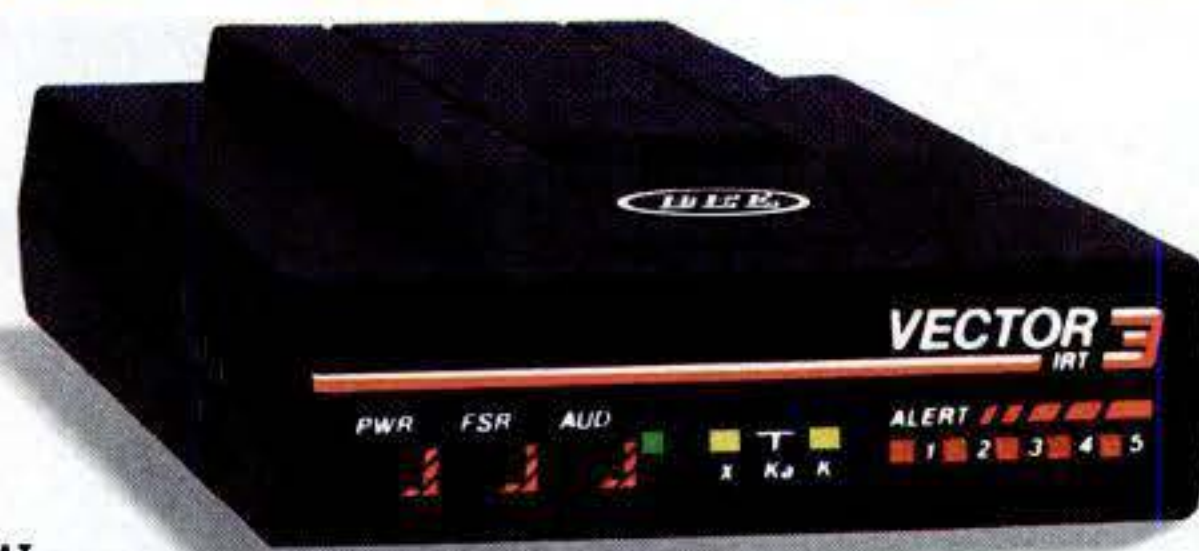
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It's not just a truck anymore. It's part of your life.

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It's going to be another special day. Because the S-15 is such a special part of your life. The S-15 is no ordinary truck. It's a GMC Truck.

It's available with the most powerful V-6 in its class: the optional 4.3-liter fuel-injected Vortec V-6 that puts 160 horsepower at your command. Combined with the rear-wheel anti-lock brake system that's standard this year, the performance is hard to equal in a compact pickup (anti-lock brakes operate only in two-wheel drive).

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DETROIT POWERS INTO '89

testers showed that the engineering changes are successful. Pedal feel and modulation are vastly improved. Stopping distances from 60

mph are now shorter by 14 feet over the last test.

Another engineering advance at Ford is the application of air bags to both front-seat positions in the 1989 Lincoln Continental. While Porsche was the first manufacturer to offer passenger-side inflatable restraints in the U.S. market, Ford can at least lay claim to domestic leadership in this area.

It's hard to imagine how Motor City could possibly survive without its global strategy

A split second after a severe impact, a folded nylon bag fills with nitrogen gas, preventing upper-body and head injuries. Pores in the bag allow it to deflate quickly. Due to the distance between the passenger and the instrument panel, the passenger-side air bag is more than three times larger than the hub-mounted driver's-side air bar.

GM: style and power

While GM has no clean-sheet automobile designs to unveil this fall, this is not to say the engineers, sculptors, and planners have been on an extended coffee break. On the contrary, the General has some catching up to do, and this year's frenzy of activity is likely only the first step.

Starting at the top, Cadillac has spurred the sales-slumping Allanté forward with a major increase in power for 1989 (see "Horsepower!"). With 200 hp on tap and a top speed exceeding 130 mph, the two-seat convertible is now the fastest Cadillac in history. It's also the first GM product to bear the stigma of a gas-guzzler tax on its price sticker, although it is doubtful that the extra \$650 will have much impact on sales of the \$60,000 two-seater.

The Pininfarina body is unaltered, except for a slight repositioning of the side-view mirror. Chassis alterations include a numerically higher axle

ratio, larger wheels and tires, new automatically adjusting three-stage shock absorbers, and power steering with speed-dependent assist. The result is a stable luxo-sport car with a confident feel and no shortage of power.

De Ville and Fleetwood models are stretched for 1989 to settle the inevitable "Mine's bigger!" arguments, at least for now. Sedans and coupes get an extra three inches tacked on the tail to improve their visual eminence and trunk volumes. And the wheelbase for sedan models is six inches longer, so the four-door model now requires an extra nine inches of parking space. The stretched interior dimensions are put to good use with only modest weight increases and virtually no fuel-economy penalty.

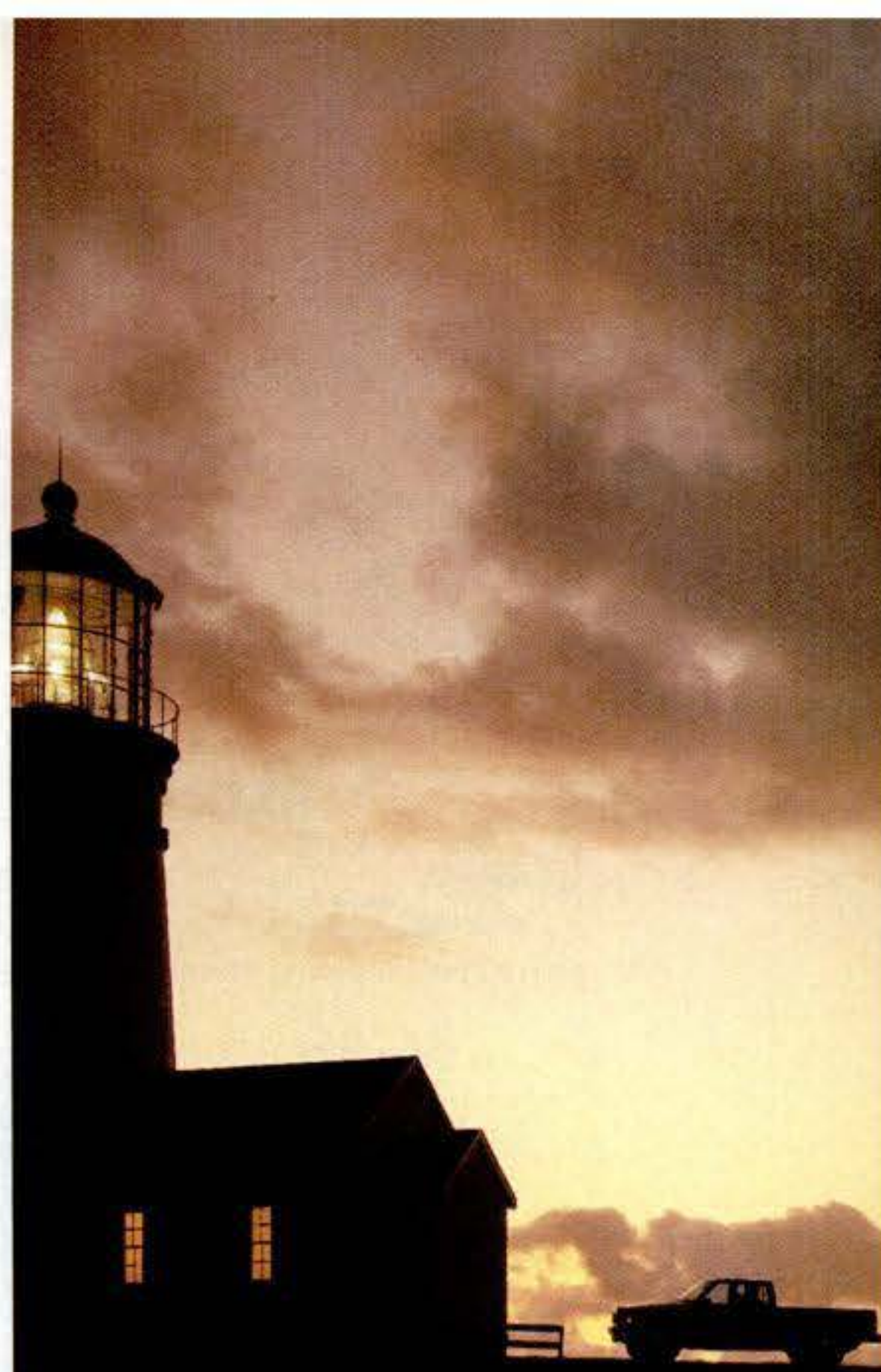
The news at Buick is sheet-metal help for the moribund Riviera line. An 11-inch addition to the tail section relieves this high-end coupe of the chopped look it has endured for three years. The new design theme is "muscular grace," and Buick has its hopes set on winning back customers. A new hydraulically damped engine-mounting system reduces both power-train vibration and torque steer.

Buick's Century four-door has a rounded roof line to reduce aerodynamic drag, and all Century models have smoother front and rear styling lines (as do the Century's sister cars, Oldsmobile Cutlass Ciera and Pontiac 6000). A reengineered 3300 V6 replaces both the 2.8- and 3.8-liter V6 engine options and improves peak power and EPA fuel economy in one fell swoop. In the spring, Buick will add a 3.1-liter V6 to the stable, first on the power-starved Regal.

Mid-year, Buick will launch a new Park Avenue Ultra flagship sedan with anti-lock brakes, two-tone paint, leather interior trim, and 15-inch wheels as standard equipment. This modern rendition of the Roadmaster will be designed to advance Buick's quest to become a builder of "premium American motorcars."

This year Oldsmobiles have more horsepower and styling alterations for the Cutlass Calais and Cutlass Ciera car lines. An intriguing color cathode-ray-tube (CRT) display and control center are offered as an option on both the Toronado and Trofeo models. In addition to managing all climate control and entertainment system functions, the CRT adds an electronic compass, a date reminder, and a message center; it also reports the status of various mechanical and electronic systems. Twenty infrared sensors mounted along the borders of the 2.6-by-3.7-inch screen accept driver or pas-

Continued



New anti-lock brakes now standard on GMC Truck S-15.

In any pickup, the one thing between you and the unexpected is your brakes. You want the best system available.

That's why the S-15 comes equipped with electronic rear-wheel anti-lock brakes designed to prevent wheel "lock-up" and help control skidding on sudden stops under a variety of road surface conditions.

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Let's get it together...buckle up.



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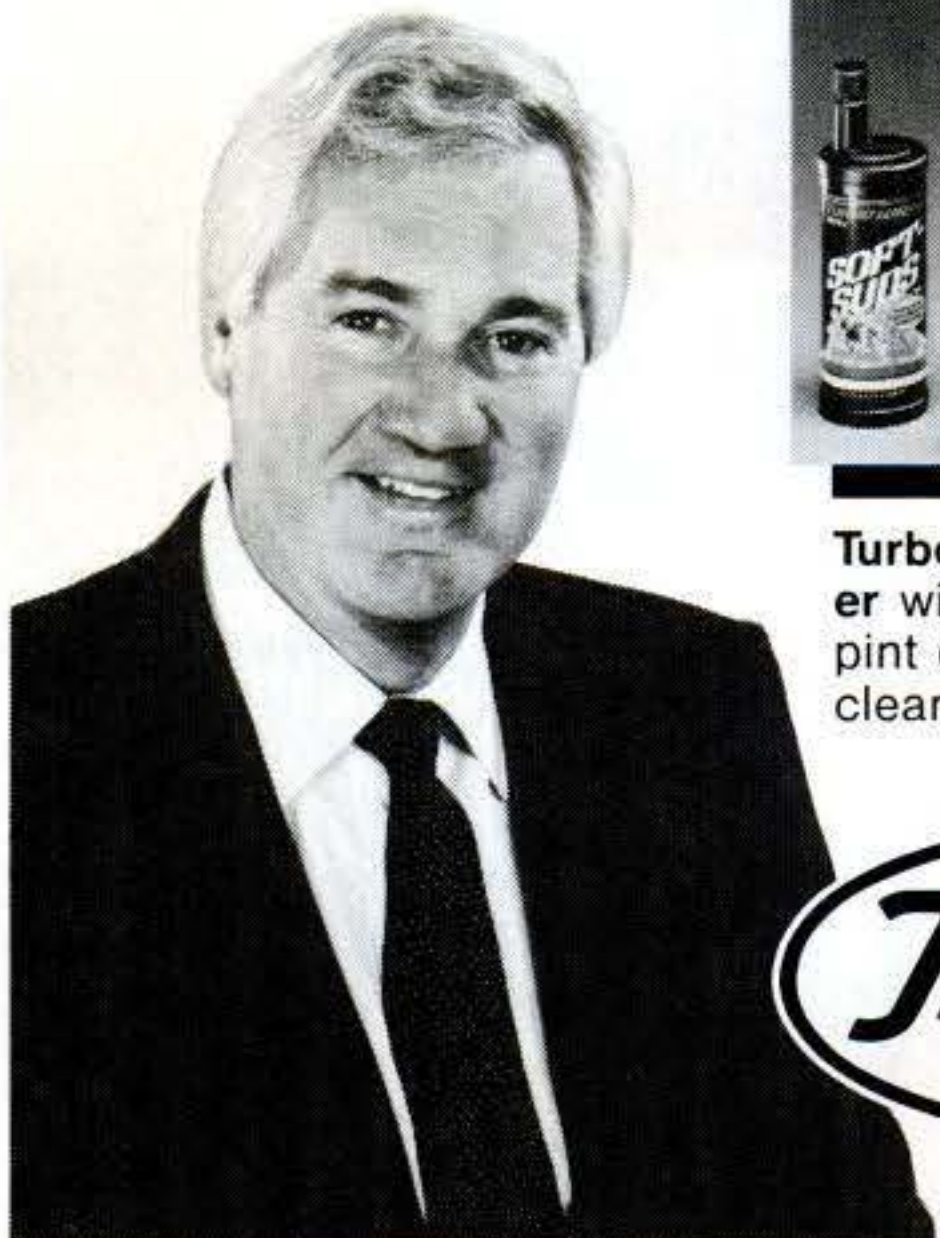


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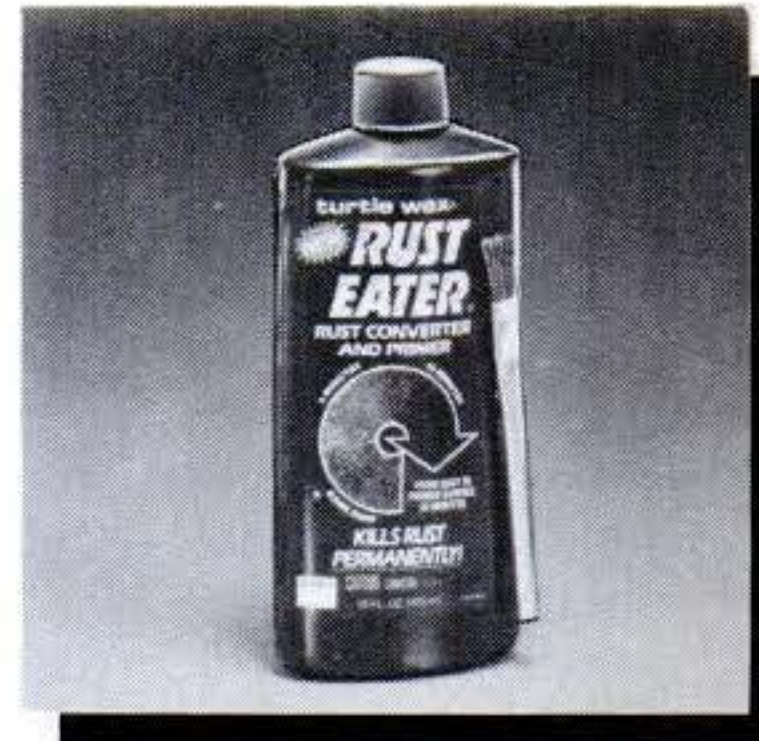


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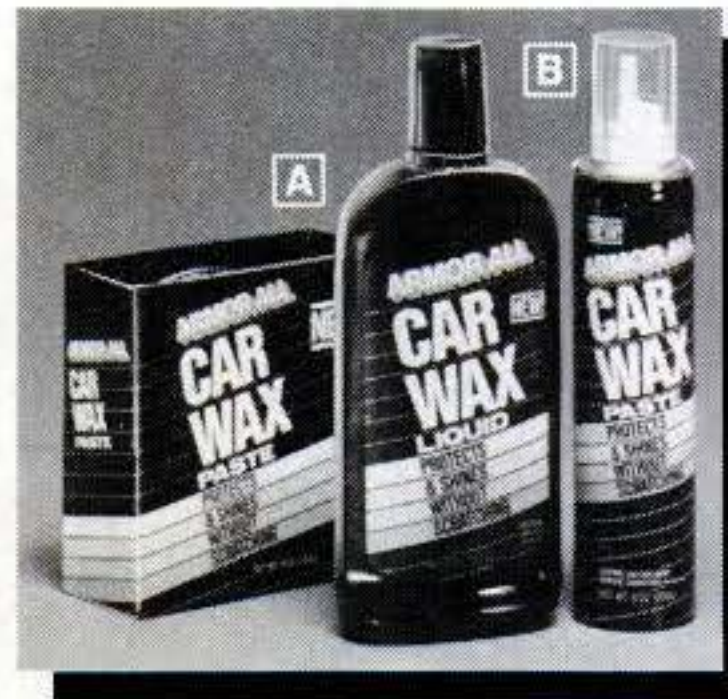
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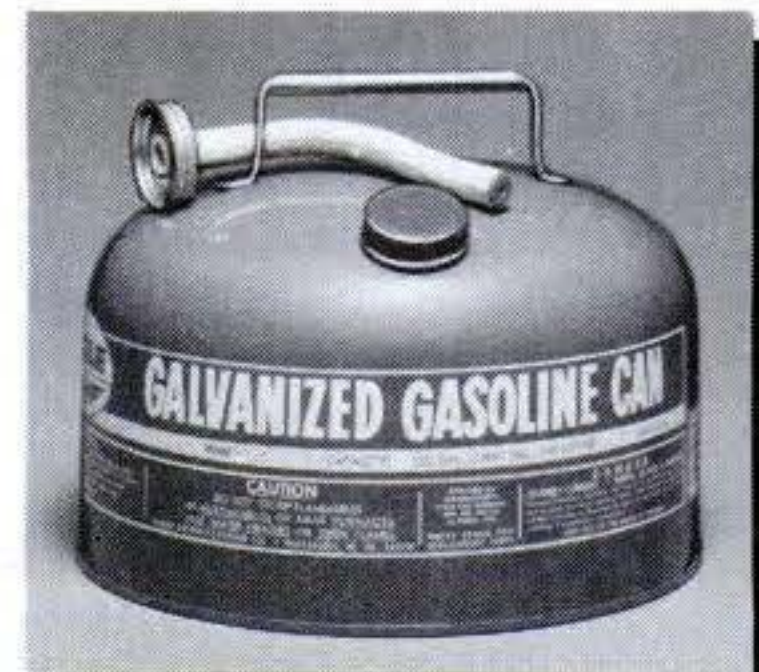
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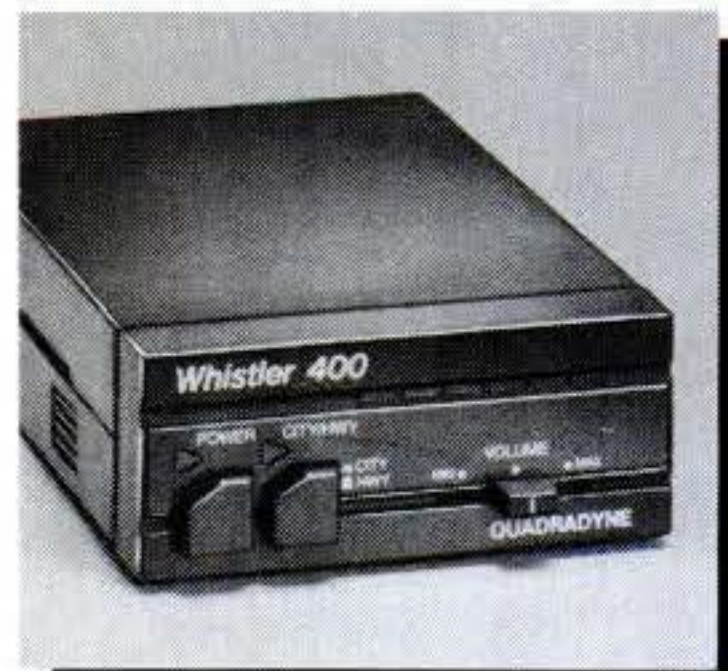
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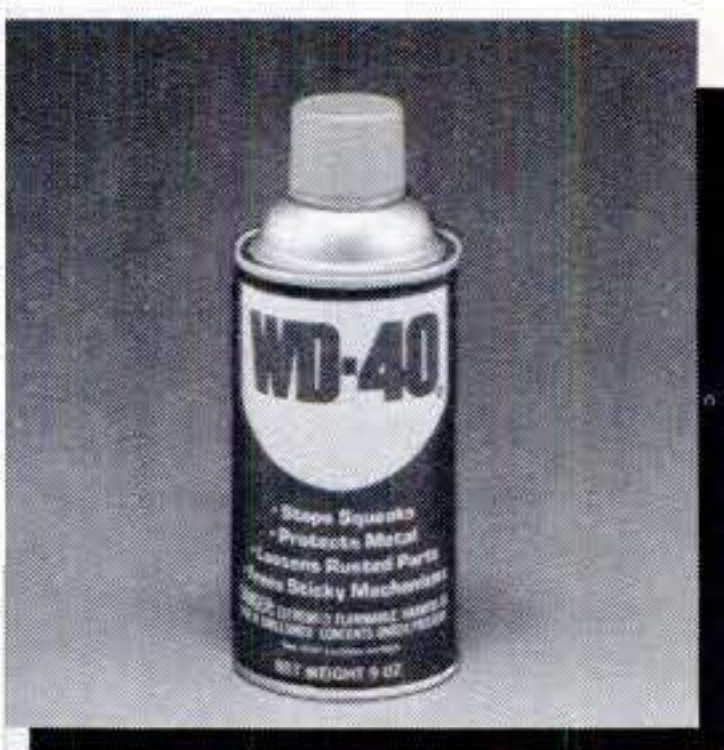
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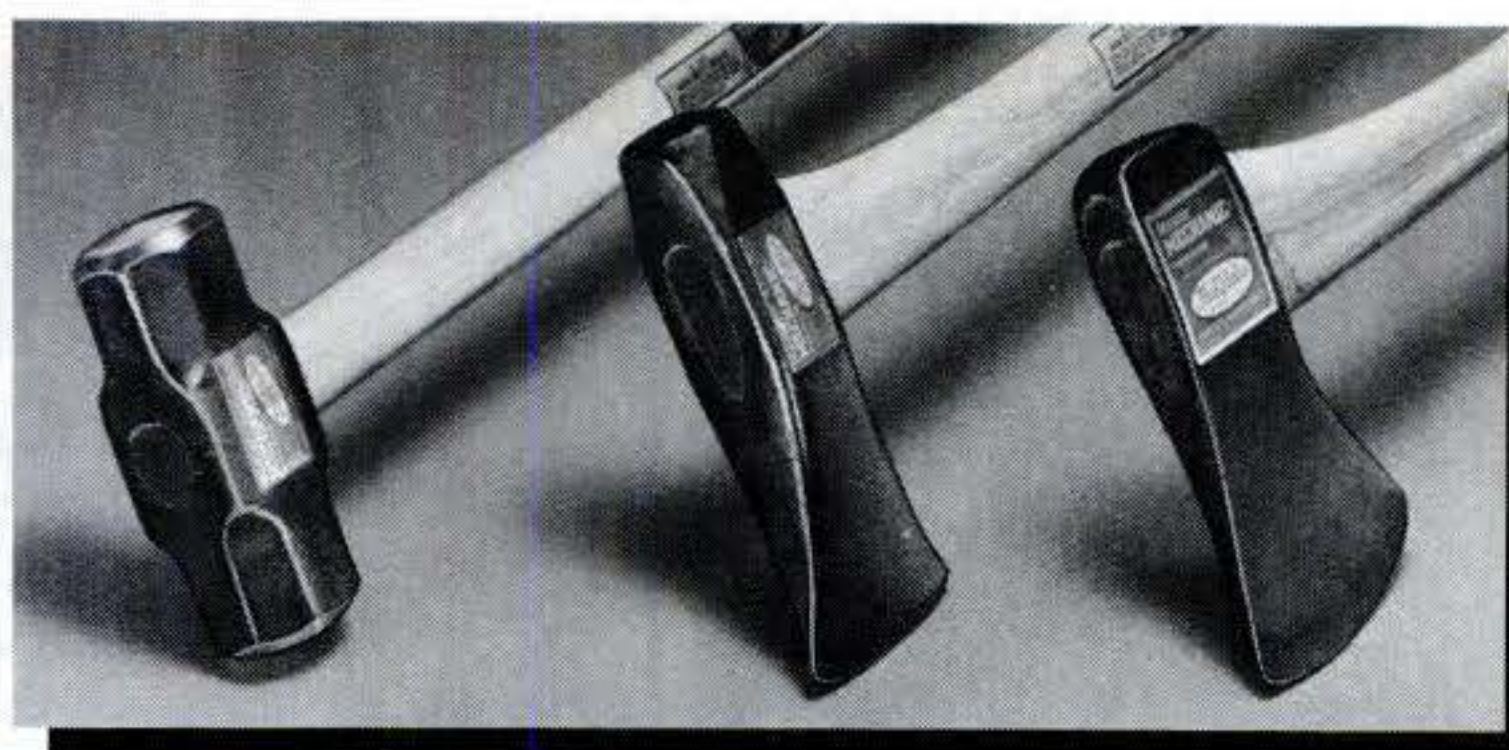
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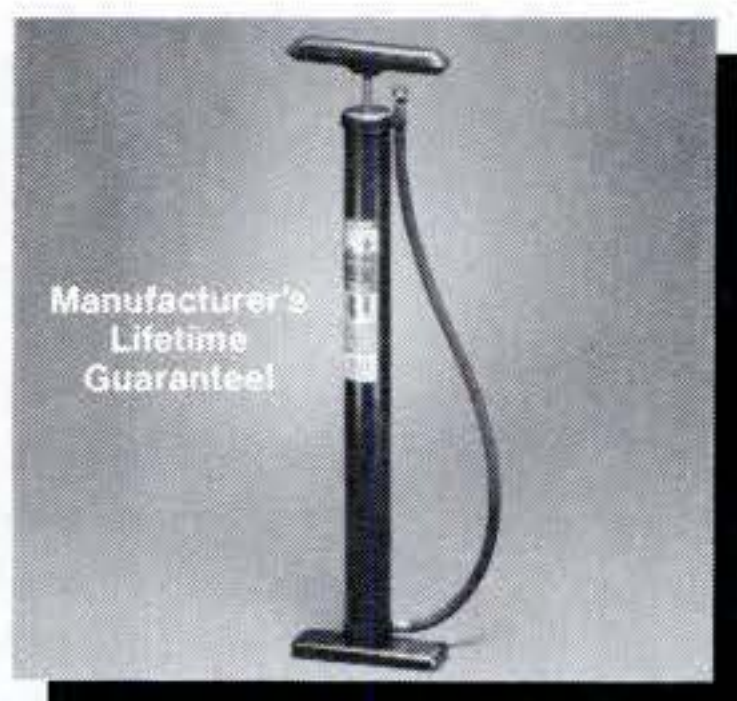
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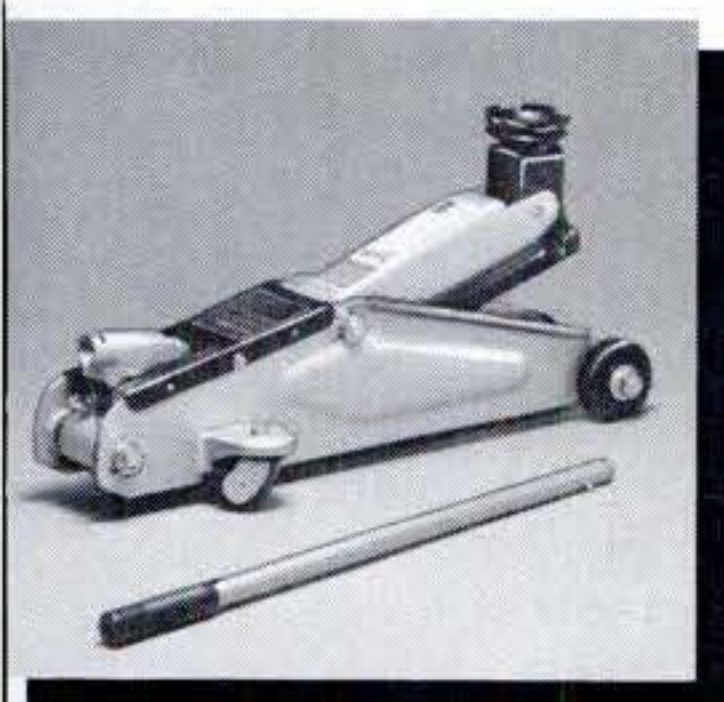
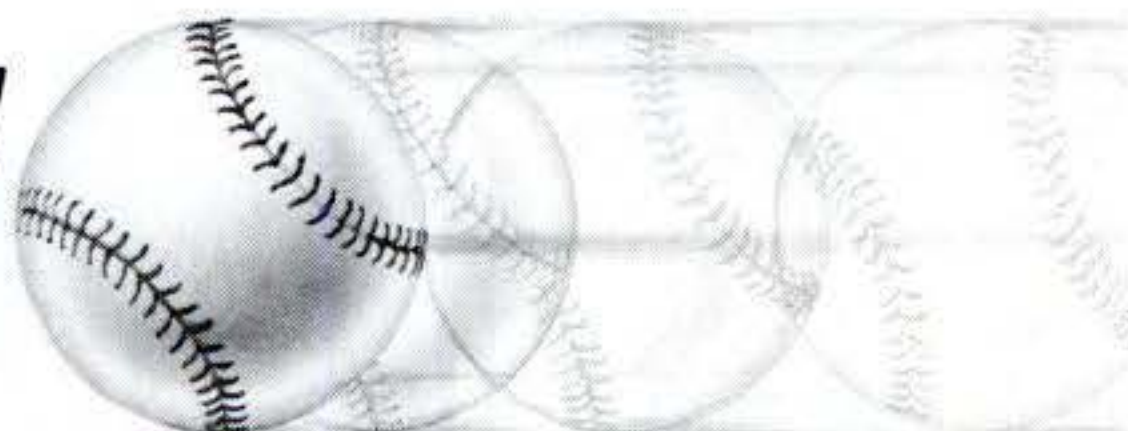


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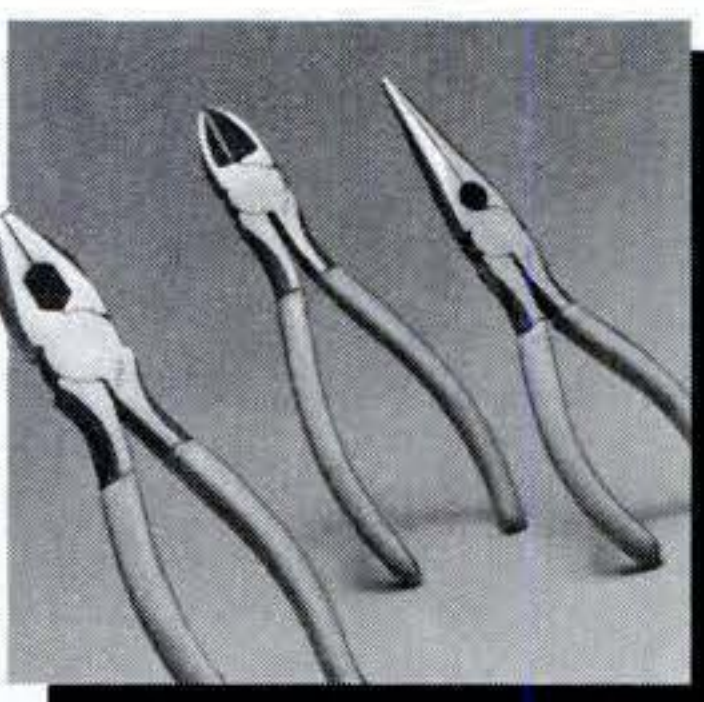
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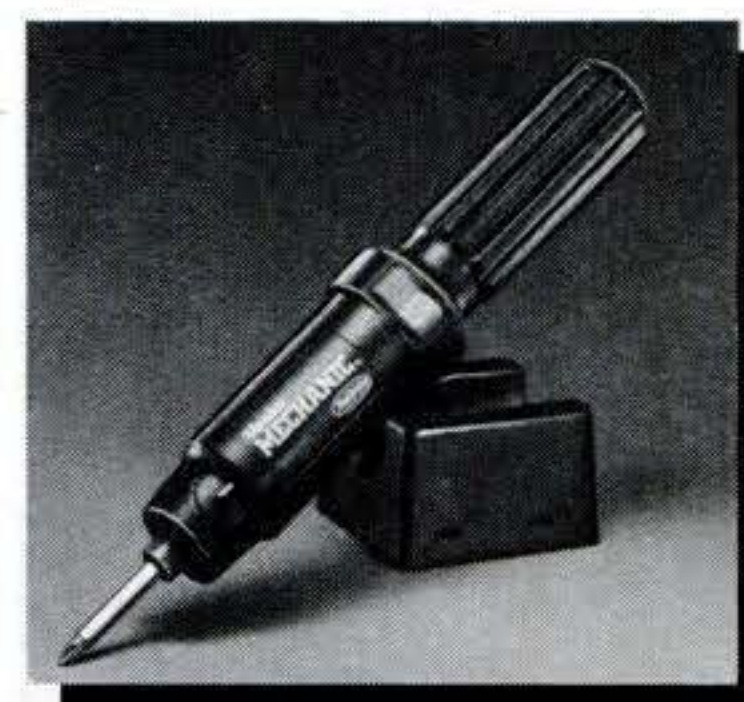
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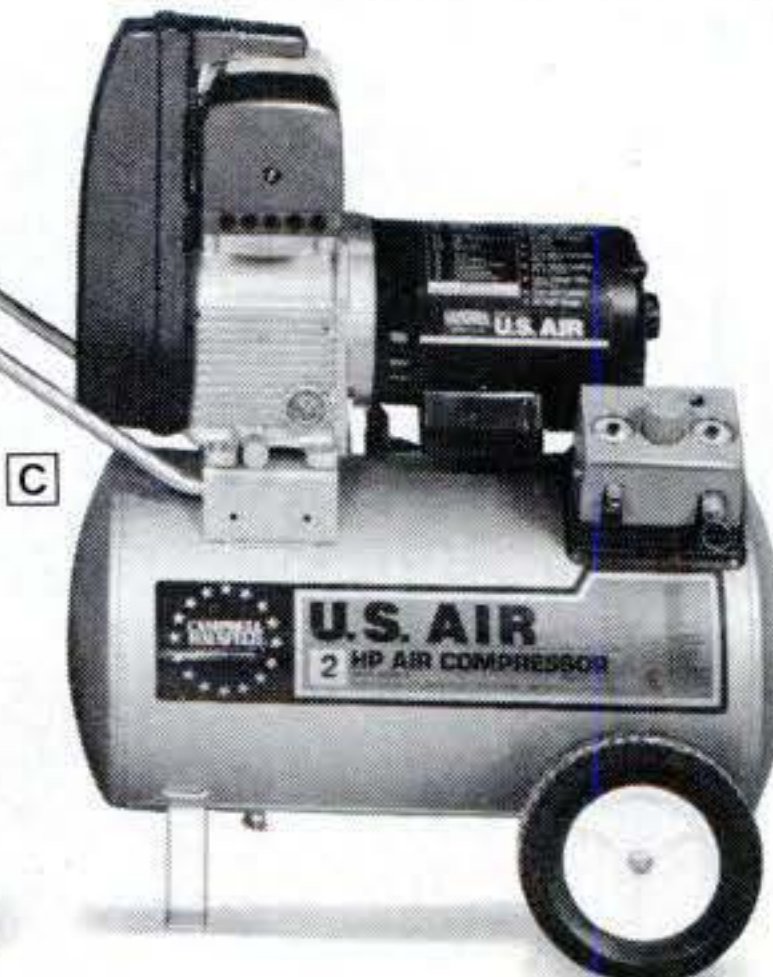
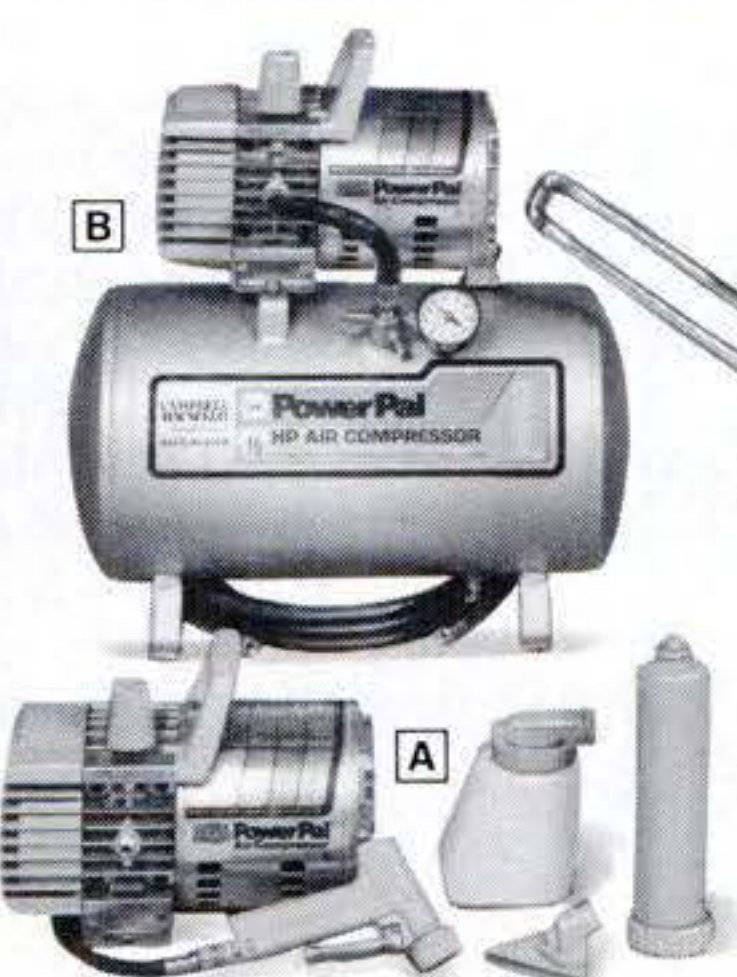
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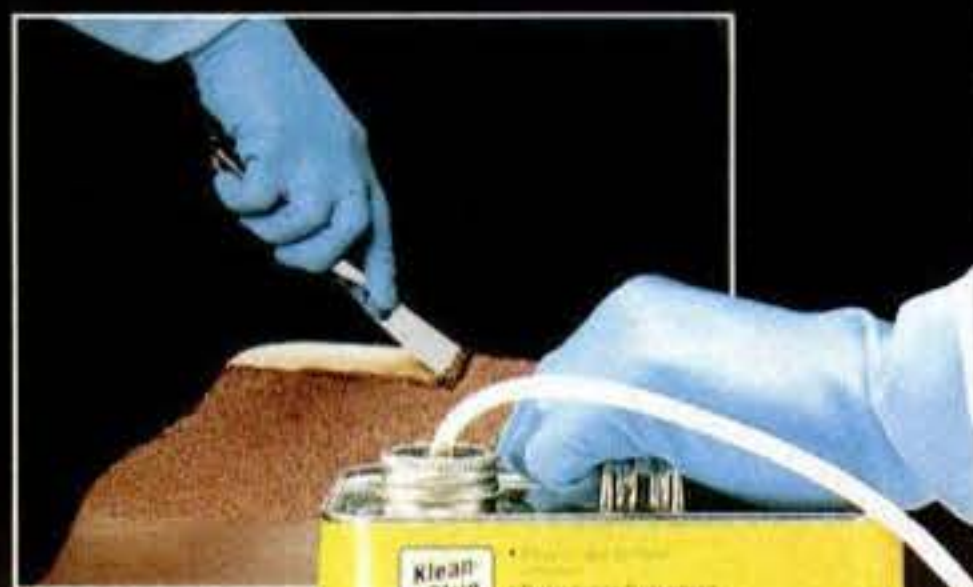
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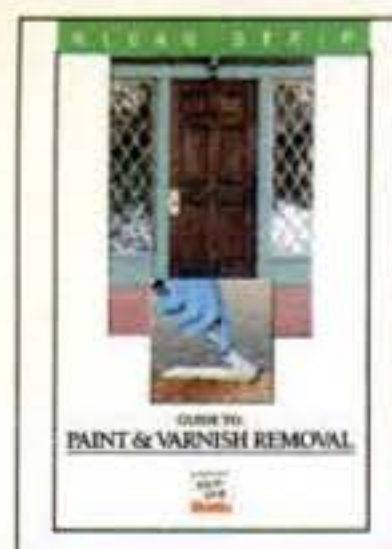


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Continued

senger inputs with no need to actually touch the screen. In addition, some functions are duplicated with large buttons adjacent to the screen.

Oldsmobile and Pontiac are cooperatively advancing the art of the instrumentation with the limited use of a special head-up display (HUD). Hughes Aircraft and Delco Electronics also participated in this program, which first saw the light of the day in Olds's Cutlass Supreme Indy Pace Car. The HUD projects virtual images from a high-intensity vacuum-fluorescent light source onto the inside of the windshield. Because the image is in the driver's peripheral field of view, the driver needn't avert or refocus his eyes from the road to obtain pertinent operating information.

While prototypes only display car speed, the '89 limited production run will also show turn signals, low-fuel warning, and a high-beam indicator. The small green numerals of the HUD unit are easy to read; however, they are all but obliterated when driving in direct sunlight.

Trans Am turns 20

In celebration of the Trans Am's 20th birthday, Pontiac will make 1,500 special anniversary models painted white with a camel-colored interior. A hot turbocharged 3.8-liter V6, last seen in the 1987 Buick Regal GNX, will provide 245 hp and a hefty 340 pound-feet of torque.

The new-for-'89 Grand Prix will get a boost up the horsepower ladder with its own turbocharged V6. Two thousand McLaren Turbo Grand Prix's will be manufactured with a 3.1-liter turbocharged V6 (delivering 205 hp), a four-speed automatic, 16-inch wheels and tires, red-ore metallic black paint, and special exterior decor.

With all the attention lavished on Pontiac and Olds, this shapes up as an off-season for Chevrolet. Its one new model due during '89, reportedly named Lumina, will be a four-door sedan version of the GM-10 (Grand Prix, Cutlass Supreme, Regal) and probably won't appear until summer.

To tide new-car shoppers over, Chevrolet has a bevy of imported models to brag about. All cars produced by Chevy's foreign partners—Toyota, Isuzu, and Suzuki—are now grouped under the heading Geo. That nameplate will encompass four entries for 1989, three of which are brand new. While these models will be sold solely at Chevrolet dealerships, they wear Geo identification, with no Chevrolet or GM badges whatsoever.

The Geo Tracker is a four-wheel-drive sport utility vehicle manufac-

Continued

Detroit goes global

Continued

tured by Suzuki in Ontario, Canada. Essentially a grown-up Samurai, the Tracker has a short wheelbase, a wide track, a coil-spring suspension, and a 1.6-liter four-cylinder engine with either a five-speed manual or an automatic transmission. Only 12 sales areas will offer the Tracker in 1989, but it is slated for nationwide distribution in 1990.

The Geo Metro is a replacement for last year's Suzuki-built Chevy Sprint. Powered by a one-liter, throttle-body-fuel-injected, three-cylinder engine, the micro-car has a highly aerodynamic body styling. Economical gas mileage will surely be a major selling point.

The Geo Prizm is a kissing cousin to the Toyota Corolla. Built in Fremont, Calif., it will replace the Chevrolet Nova after New Year's Day as a 1990 model.

The one carry-over Geo model, the Isuzu-built Spectrum, was thoroughly overhauled last year. It is back with more-modest equipment aimed at attracting more entry-level buyers and those interested in a second car.

Chevrolet's import binge also brings noteworthy performance changes to the Corvette. A new six-speed manual transmission imported by ZF of West Germany will immediately replace the four-speed-plus electric overdrive that has been used since 1984. First and second gears deliver more torque multiplication for quicker acceleration than before, and both fifth and sixth are overdrive ratios for comfortable and efficient high-speed cruising.

Next spring the Corvette's reputation for muscle will take a major hike upward with the introduction of a new four-cam 32-valve 5.7-liter V8 cooperatively designed and engineered by Chevrolet and the Group Lotus PLC and manufactured by Mercury Marine in Stillwater, Okla.

Chrysler: K-car adaptation

Chrysler is in the thick of merging its AMC-Jeep acquisitions into one smooth-running car- and truck-building entity. Nevertheless, for the 1989 model year, the venerable K-car platform has been creased and folded again to produce a new line of "A-cars" for Plymouth and Dodge dealers. The new Plymouth Acclaim and Dodge Spirit use a wheelbase of 103.3 inches and well-proven suspension and powertrain components mixed in with a host of recent developments to create an amalgam that Chrysler hopes will catch the eye of the family-sedan buyer. Only one body style is offered: a high-roof rounded-corner four-door sedan with seating accommodation for either

four or five passengers. A balance-shaft-equipped 2.5-liter four-cylinder engine is available as a base, but more powerful options include a Mitsubishi-made three-liter V6 and a new-for-1989 turbocharged version of the 2.5-liter four-cylinder. The transaxle lineup includes a three-speed automatic, a five-speed manual, and a new four-speed electronically controlled automatic.

While the A-car offering is not a clean-sheet design, these cars are by far the most refined of the K-car clan. The engineers kept the basic suspension and structure used previously, but adjusted and tweaked every possible variable to tune this new entry for the family-sedan market.

Chrysler's import emphasis will continue with a new small car from Mitsubishi that Plymouth and Dodge dealers will sell as a Colt during the 1989 model year. Jeep-Eagle dealers will sell the same basic car as the Summit. To check intramural competition, Plymouth and Dodge will market only three-door hatchbacks while Jeep-Eagle dealers will offer only four-door sedans. All versions are front drive, and a turbocharged 16-valve four-cylinder screamer is an available option.

Next spring Chrysler Diamond-Star's joint venture with Mitsubishi will bear fruit in the form of a new U.S.-built sporty coupe to be called Laser at Plymouth dealers and Eclipse at Mitsubishi stores. Yet another spin-off of the original K-car platform is also due late in '89, wearing Chrysler New Yorker Fifth Avenue and Imperial nameplates.

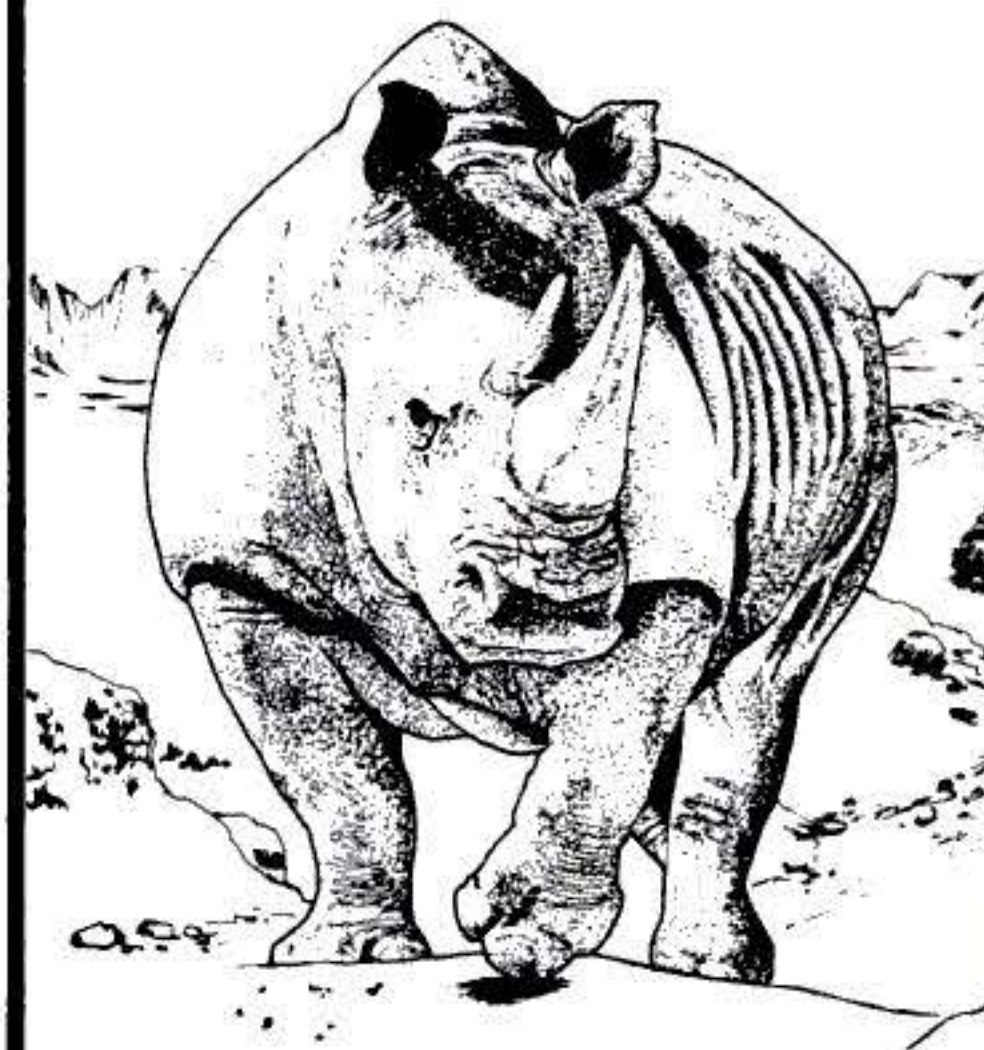
1989: introduce when ready

This may not seem like a banner year for domestic product launches, but that's only because new model introductions are no longer clumped into the month of October. Redesigned cars hit the showrooms the instant they're ready, even though the timing may be out of phase with the traditional fall hoopla at dealerships.

Nevertheless, 1989 will go down in motor history books as the year that Detroit well and truly acknowledged that the automotive world extends far beyond U.S. borders. Looking back on the '80s, it's clear that the internationalization of Detroit is a major accomplishment. Contemplating the '90s, it's hard to imagine how Motor City could possibly survive without its new global strategy. **PS**

The author has covered the auto industry for 17 years. He has a master's degree in mechanical engineering.

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Horsepower! [Continued from page 24]

new cylinder heads and a low restriction exhaust system. We clocked 8.6-second 0-to-60 times with the new power plant, compared with 9.7 in an earlier test.

GM has also introduced a new 3.1-liter V6, which is essentially a longer-stroke version of the old 2.8-liter engine. The new power plant enhances drivability using its greater torque range.

Chrysler didn't have anything to show that was quite as spectacular as the efforts at GM and Ford. While the

company awaits the arrival of a new V6 that is essentially a chopped-off version of its bulletproof V8, it has been relying heavily on its Mitsubishi-built three-liter V6 to fill in power gaps.

Big brother to the rescue

Meanwhile, a few more chinks in Chrysler's lineup are filled in 1989 with a new turbocharged 2.5-liter four-cylinder that produces 150 hp at 4,800 rpm and 180 lb.-ft. of torque at 2,000 rpm. Chrysler's "Old Paint" 2.2-liter,

in standard and turbocharged versions, thus gets a smoothed-out and higher-torque big brother. The 2.5-liter four-cylinder is also noteworthy in having counterrotating balance shafts to smooth it out.

Applications include a new 2.5-liter turbo option for the minivan, a combination that seems to exist mainly because of a developing shortage of the Mitsubishi V6.

In the company of all the high-performance power plants, Chrysler is introducing one new engine that stands out in the crowd the same way a recently insulated water buffalo does at a tea party. Cummins Engine Co., best known for its heavy truck engines, is making a 5.9-liter turbocharged, direct-injection diesel engine for Dodge 250, 350, and chassis cab trucks. The engine competes with similar truck-based diesels offered by Ford and Chevy in their larger pickups, but is the first with a standard turbo and one of the first times direct injection has been used outside the commercial arena.

Direct injection vastly improves fuel economy, but limits the rpm range of the engine. Chrysler mates the slow-turning diesel well with gear ratios that make it at least quick enough to remind you of a drag-racing ox cart. It's also the only vehicle that I have ever had to turn off at the fast-food drive-in speaker box so they could hear my food order. However, it has tremendous potential trailer-pulling ability, high torque rise, and overall durability.

Only the beginning

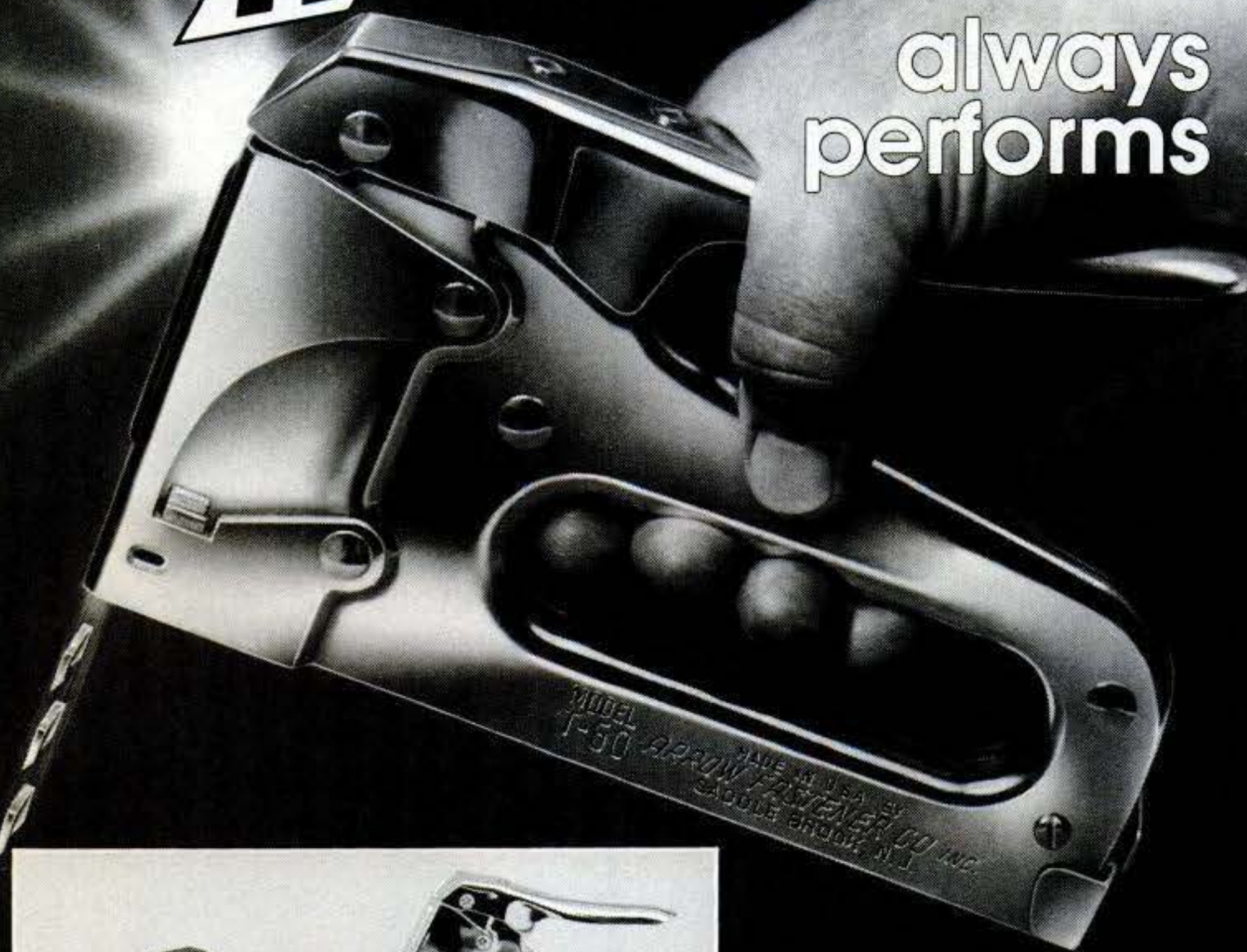
At the end of the tour, I was left with the feeling that this was only the beginning of a new era in domestic engine design. The LT5 engine is likely a high-water mark for raw power, unless Ford is sucked into a flat-out horsepower race. But the future still holds a new family of engines coming from Ford, and a new series of multi-valve efforts from GM. Chrysler, likewise, will soon have a variable-geometry turbocharger to counter Ford's new supercharger as well as the aforementioned V6 and a rumored new V10.

Impressive as the showing was, I felt the most glaring no-show was a small-displacement domestic engine smooth enough to compete with the best from Japan and West Germany. But with the engines that are on tap for '89, it's clear that there's enough power here to keep most competition in the rearview mirror, along with some technological achievements that will influence engine design far into the future.

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"Say, Smokey—"

A clinic on cars by Smokey Yunick, America's most famous mechanic

Belt-test update

In your response to C. Alley's question on seat-belt reliability [July], you stated that "a simple test to check a seat belt's inertial reel locking mechanism consists of giving the belt a sharp, quick tug" to verify lockup. This is not a good test and may lead owners to needlessly thinking their belt systems are defective. Belt retractor lockup can only be checked in a vehicle by positioning the shoulder belt snugly against the chest. With the lap-belt portion properly adjusted, perform a brake stop at approximately 5 mph. The belt should catch you and lock as you move forward. The proper information and techniques are in owner's manuals.

Richard E. Collett
Design Analysis Engineer
Ford Motor Co., Dearborn, Mich.

Sorry about the confusion. There are many seat-belt systems, including one with a pendulum that controls the belt-locking mechanism and one that uses a small explosive charge to take up any slack in the belt. All require periodic checking. The best advice I can give is to look it up in your car's owner's manual. Thanks for the helpful information.

Broken head bolts

I have a 1985 Buick Skylark with a four-cylinder engine. Two of the cylinder-head bolts have broken while I was driving the car. When I tried to drill the broken bolts to accept a stud remover, I found that only one of them was soft enough to be drilled. The other one was so hard that I had to tap it out with a center punch and a chisel. The bolts are installed at 85 pound-feet of torque. Do you think stainless-steel bolts would be better for this job than the hardened bolts used by the factory?

G. Bemberg, Miami, Fla.

It sounds to me as if Buick had a bad batch of cylinder-head bolts when they built your engine. Head bolts are made according to strict specifications for material and heat treating, and are designed to be precisely torqued when the engine is assembled. I think you would be best off replacing all of the head bolts in your engine with new ones

from Buick. Also, use new gaskets and torque the head bolts to factory specifications. I bet this cures the problem.

Rapid brake wear

I've replaced the rear-brake linings in my 1984 Renault Encore three times over 50,000 miles, whereas the original front-brake pads are still in good condition. I have never driven the car with the emergency brake left on.

G. Brooks Davis Jr., Houston, Texas

The next time you service the rear brakes, install a set of metallic-compound linings. They cost more and may squeal when they're cold, but they will also last a lot longer.

Shake, rattle, and roll

I have a problem with high-speed vibration, which seems to come from the front end of my 1982 Ford LTD station wagon. The car has 57,000 miles on it, and the steel-belted radial tires have about 20,000 miles on them with normal wear. At 50 to 55 mph the vibration is noticeable in the hood, steering, and seats. But at 60 mph the vibration fades and is eventually gone. Do you have any suggestions?

Bill Sherman, Miami, Fla.

There are many possible causes for front-end vibration. First, you need round, balanced wheels and tires (less than 0.06-inch runout up and down, and less than 10 ounces out of balance side to side). Next, the hubs and brake rotors or drums must be in balance, so try having the wheels balanced while they're on the car. But remember, wheel balance can come and go with speed, depending on the tire's shape. A bad tire can go crazy at 60 mph, clear up at 65 mph, and become unstable again at higher speeds. On top of all that, there should be no play in steering and suspension parts, and shock absorbers must be in working order. Front-end alignment settings should be in the ballpark range. Here, the wheel's caster adjustment is most critical, and toe-in is next in importance.

Rear-axle aches

I own a 1983 Oldsmobile 98 Regency that has a nagging problem with its limited-slip differential. On slow turns

Continued

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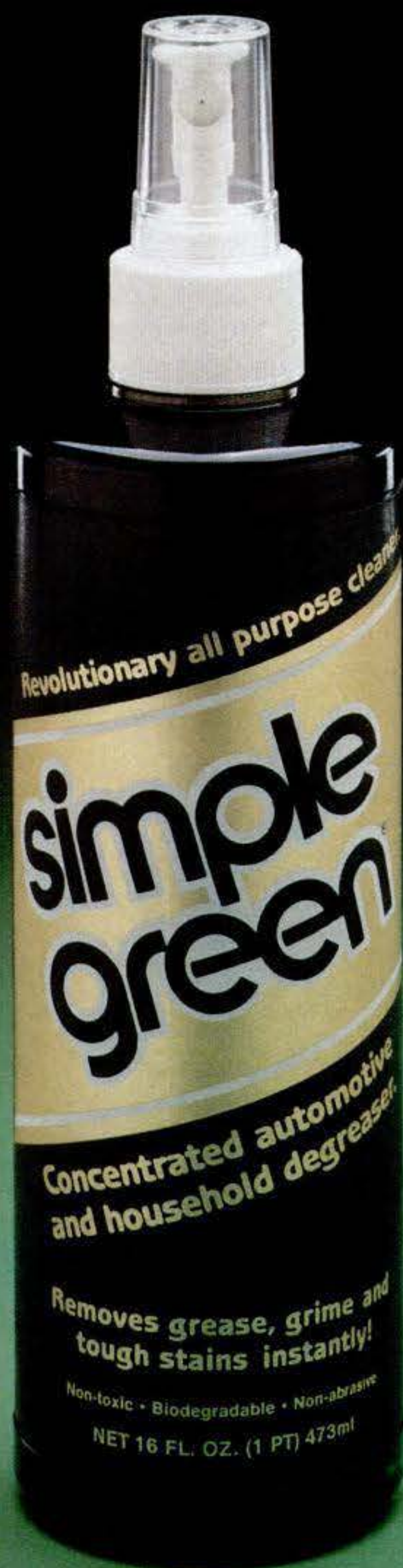
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"Say, Smokey—" *Continued*

the rear end makes a chattering noise. Using a whale-oil lubricant in the differential reduced the noise, but there is still a pulsating clanking when moving slowly in traffic. Can you suggest a cure?

John B. Rogers
Stockbridge, Mass.

It doesn't sound as if you'll find a lubrication-chemistry cure for your problem. Try checking to make sure both tires are the same diameter. Just going by the size embossed on the sidewall isn't enough. Measure them, because they can wear differently. If they are the same and the noise persists, disassemble the differential and look for worn, broken, or loose parts.

Driving oil disposal?

The local garages have stopped taking my used motor oil. Because I have a diesel pickup truck, I was wondering if it possible for me to mix the used oil in with the diesel fuel and burn it in my truck. Would pumping the diesel-oil mixture through a diesel fuel filter before pouring it into the tank protect my injectors?

William J. Grimes
Winter Garden, Fla.

If I were you I'd forget that idea about mixing spent oil in with your diesel fuel. You probably have enough trouble getting clean, proper diesel fuel from gas stations as it is. Spent crankcase oil contains a witch's brew of sludge, metals, and carbon, and has no place being mixed with your diesel fuel. Check with the dealer authorized by your community's waste-oil disposal plan about where and how to get rid of your dirty oil. However, disposing of used lubricants can at times cost as much as the oil itself. If you really want a headache, try getting rid of an old battery or tires.

Detergent injection

Do you have any information about the detergents used in regular and premium grades of unleaded gasoline? I understand that poor-quality fuel can easily clog fuel injectors, but are all brands the same? And how much is enough? How about carburetor/fuel-injector cleaners?

Tom Bissonette, Waterloo, N.Y.

Your question about gasoline detergents opens up a real can of worms. Every day, it seems, automotive and chemical engineers come up with changes in additive packages for fuel

and lubricants. As a rule, the chemistry is proprietary, and companies are less than candid about making that information available to the public. The small orifices used in fuel injectors require high-quality fuel and distribution parts that are hospital-clean. I think it's obvious these fuel injectors are not as trouble-free as carburetors, but I doubt that the fuel-injection systems we see today are the final word on this technology. I expect systems less subject to fuel problems to come onto the market as the evolution of cars continues. As to your question about gasoline additives for cleaning injectors, they are about the same as other preventive-maintenance chemicals. Some are useful in keeping fuel-system parts clean, but are ineffective if used after the damage is done. Because you have no way of knowing the condition and contents of the fuel you are buying, it is hard to know how much and when to use these products. So at best, it's a guess.

Turbo parts fryer

I have a 1979 Buick Riviera with a rebuilt 3.8-liter turbocharged V6 engine. The driver's-side exhaust manifold gets red hot and sometimes almost white hot. Every time I stop the engine, it backfires once. I have had the car for four years and have had to replace the exhaust-manifold gasket twice and spark-plug wires regularly. What is the trouble?

Kenneth R. Snyder, Waynesville, N.C.

All turbochargers run hot, with some parts operating between 1,700 and 1,850 degrees F. Heat can quickly build up in the exhaust if the pipes are undersized or if there is a restriction. Your best bet is to look for a plugged catalytic converter, bad muffler, or squashed tailpipe. Open up the blockage and the engine will be better able to get rid of its excess heat. The backfire is most likely the hot exhaust system igniting residual unburned fuel in the exhaust. As for the plug-wire-burnout problem, you can get special wires that withstand high temperatures. To reduce electrical noise, be sure the replacement wires are compatible with the ignition system. If that doesn't help, try relocating plug wires away from heat sources, or install a small aluminum or stainless-steel box to act as a thermal barrier.

Got a car problem? Send it to "Say, Smokey—," POPULAR SCIENCE, 380 Madison Ave., New York, N.Y. 10017. All letters are read, and those of widest interest are answered in this column. Due to the large volume of mail, Smokey cannot reply to letters not selected for publication.

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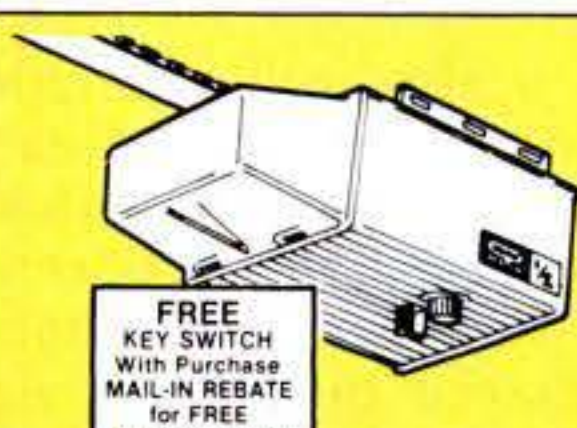
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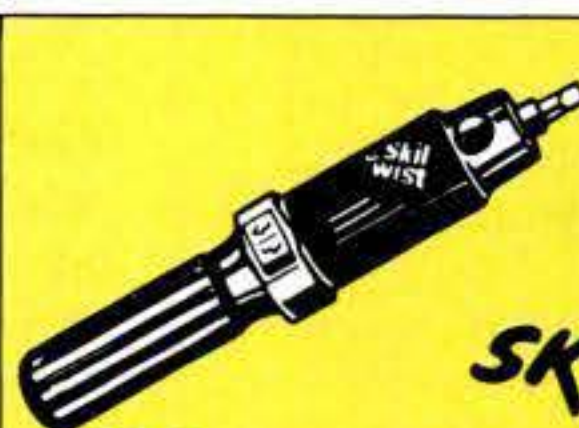
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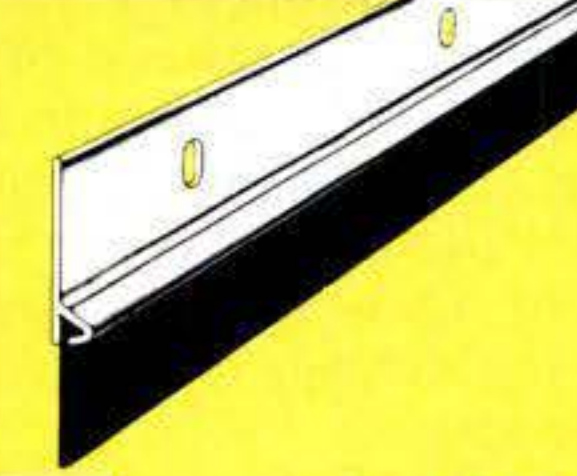
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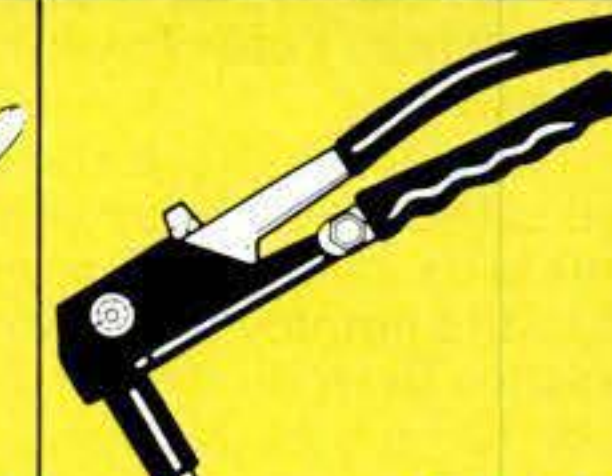
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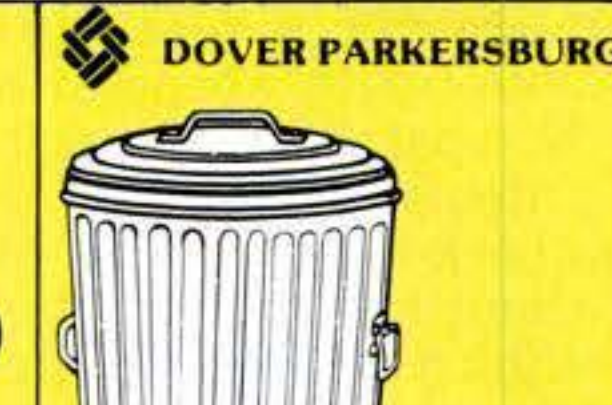
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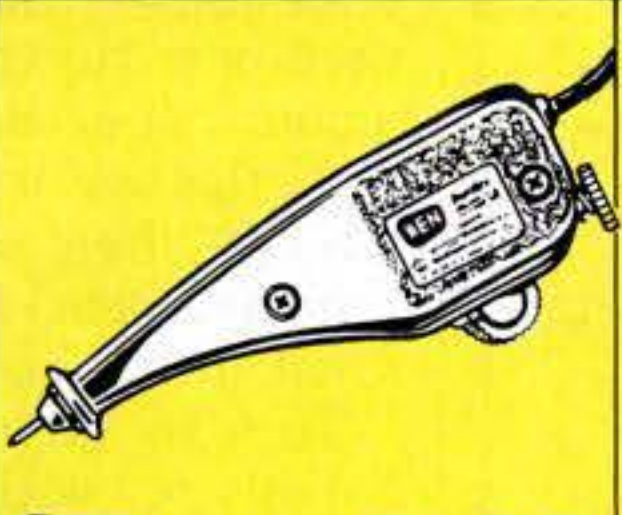


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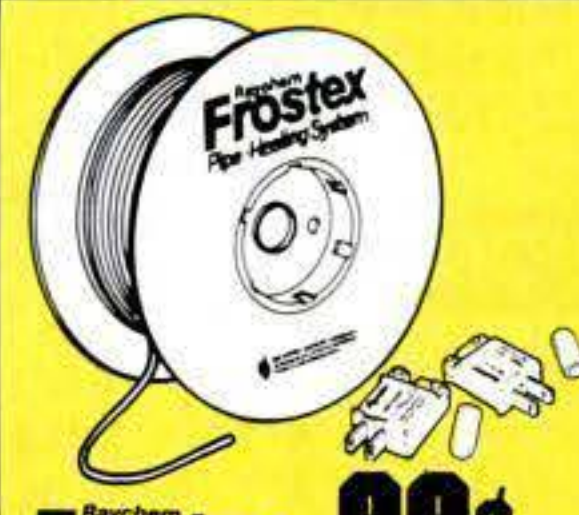
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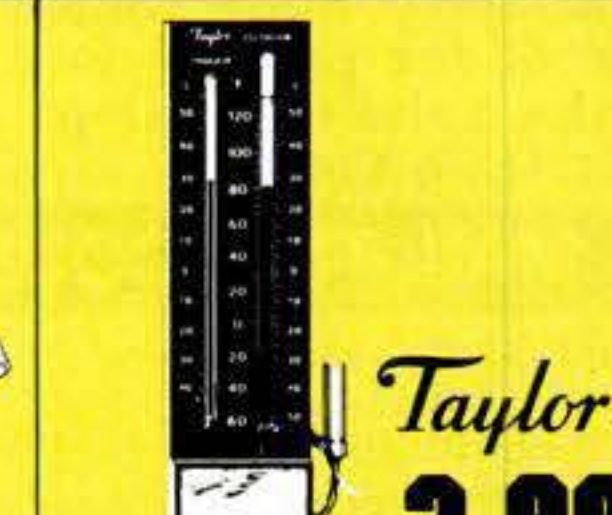
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Juice sleuths

In May the Beech-Nut Nutrition Corp. paid a \$250,000 fine to New York State to end a case in which the company was charged with selling adulterated apple juice for babies. The state said the "juice" was really apple-flavored sugar water.

A decade ago officials probably wouldn't have been able to spot the phony juice. But tests developed in recent years have enabled scientists to detect the types and amounts of sugars and acids present in juices. The crooks, aware of these tests, have found new tricks. But like biologists who seek new pesticides, food experts have tried to stay one step ahead of the mutating juices.

"Prior to the eighties we had poor methodology for picking up juice adulteration, unless it was really flagrant," says Dr. Elmer George, director of the food laboratory at the New York State Department of Agriculture and Markets. But by the time researchers analyzed Beech-Nut's juice, they had new weapons. They had begun testing for polyphenolic acids present in real juices. They were also measuring the relative amounts of sugars using high-performance liquid chromatographs.

"The sugar profile was not typical," George recalls. "But the real tip-off was the absence of two of the polyphenolic acids." A chemist concocting synthetic juice could have stirred in the proper acids, he says, "but they're quite expensive ingredients."

In the past, tainted juices usually contained cheap syrups made from sugar cane and corn. Because sucrose from these plants has more naturally occurring carbon-13 isotopes than does sucrose from juice, many labs perform isotope analyses. "But it didn't take the criminal mind long to find a way to avoid the system," says Leonel Sternberg, a biology professor at the University of Miami who studies orange juice. "They figured out if they used beet sugar, which has the same amount of carbon-13 as orange juice, then the test wouldn't detect the difference." Beet sugar is now the most common form of orange juice adulteration in this country.

To fight the cheats who use beets, Sternberg, with scientists from the U.S. Department of Agriculture and the University of California, devised a method of measuring hydrogen- and oxygen-isotope levels, which are different for orange and beet sucrose. The tests may also be used to check apple juice, wine, and honey.—Dawn Stover

Radar rescuer

A half-hour after a springtime avalanche last year near Parpaner, Switzerland, a woman lay beneath three feet of snow. Though unconscious, she was still alive. Earlier that day, the woman had purchased a pair of band-aidlike strips called Personal Locators. Within nine minutes of starting a search, a rescue team found her. Those strips saved her life.

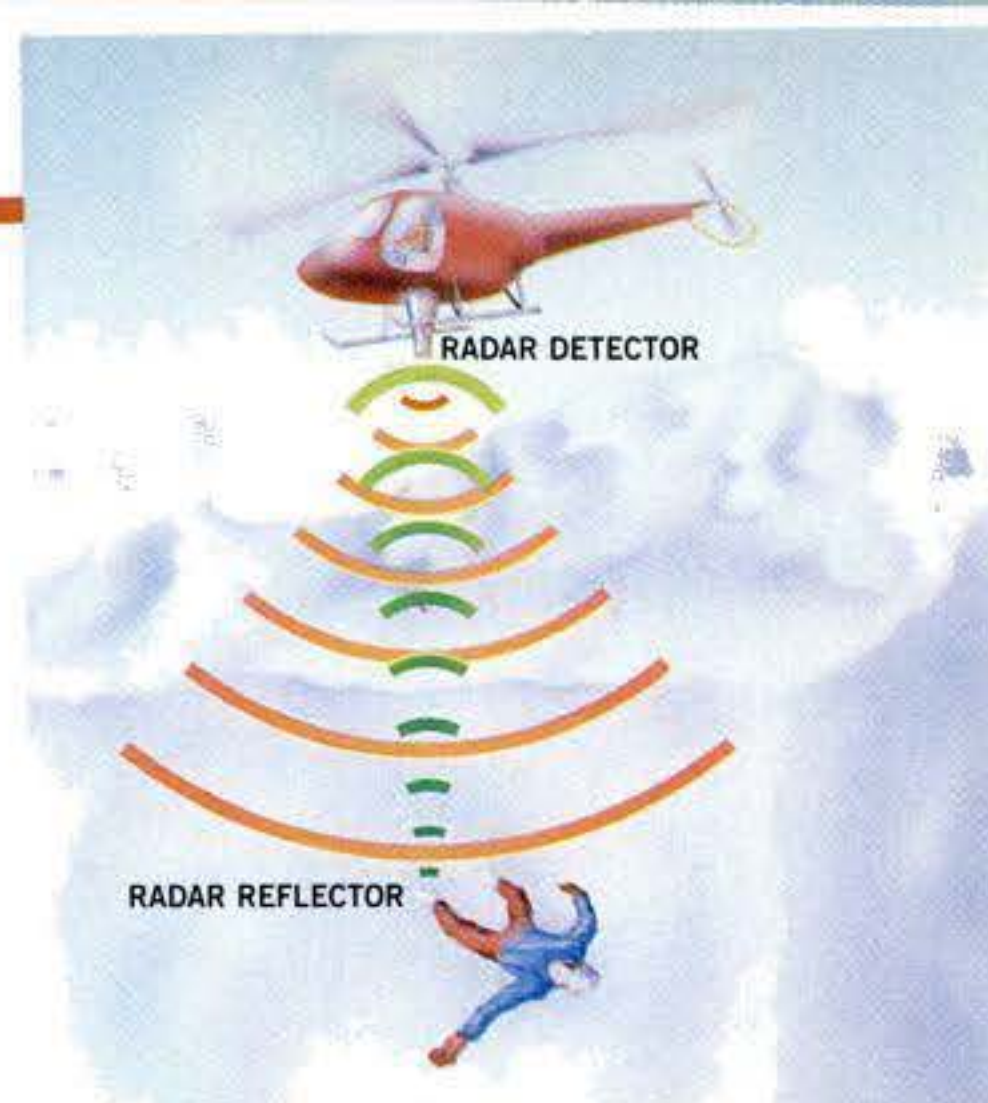
The new rescue devices (below) are tiny transponders that stick onto boots or clothing, enabling rescuers to find avalanche victims or lost hikers rapidly, says the maker. They are part of an electronic tracking system developed by Recco Rescue of Irvine, Calif. In use, the locator alters and retransmits a microwave signal emitted by a detector, which can be hand held or mounted in a helicopter. The detector consists of a gunlike directional antenna, a transceiver, and headphones. The antenna picks up the locator's return signal and converts it into a tone in the headphones. Lights on the antenna measure the tone's intensity with changes in direction, allowing rescuers to home in on the victim.

"With a helicopter, the detector can scan an area of up to 31,000 square feet per minute," says Randolph Clyne, Recco president. "It can locate some-

one as far away as six hundred feet."

Personal Locators cost \$20 a pair and need no maintenance or batteries.—*Eduardo R. C. Capulong*

A detector emits a microwave signal, which locators alter and reflect back. The return signal can penetrate up to 30 ft. of snow, says the maker.



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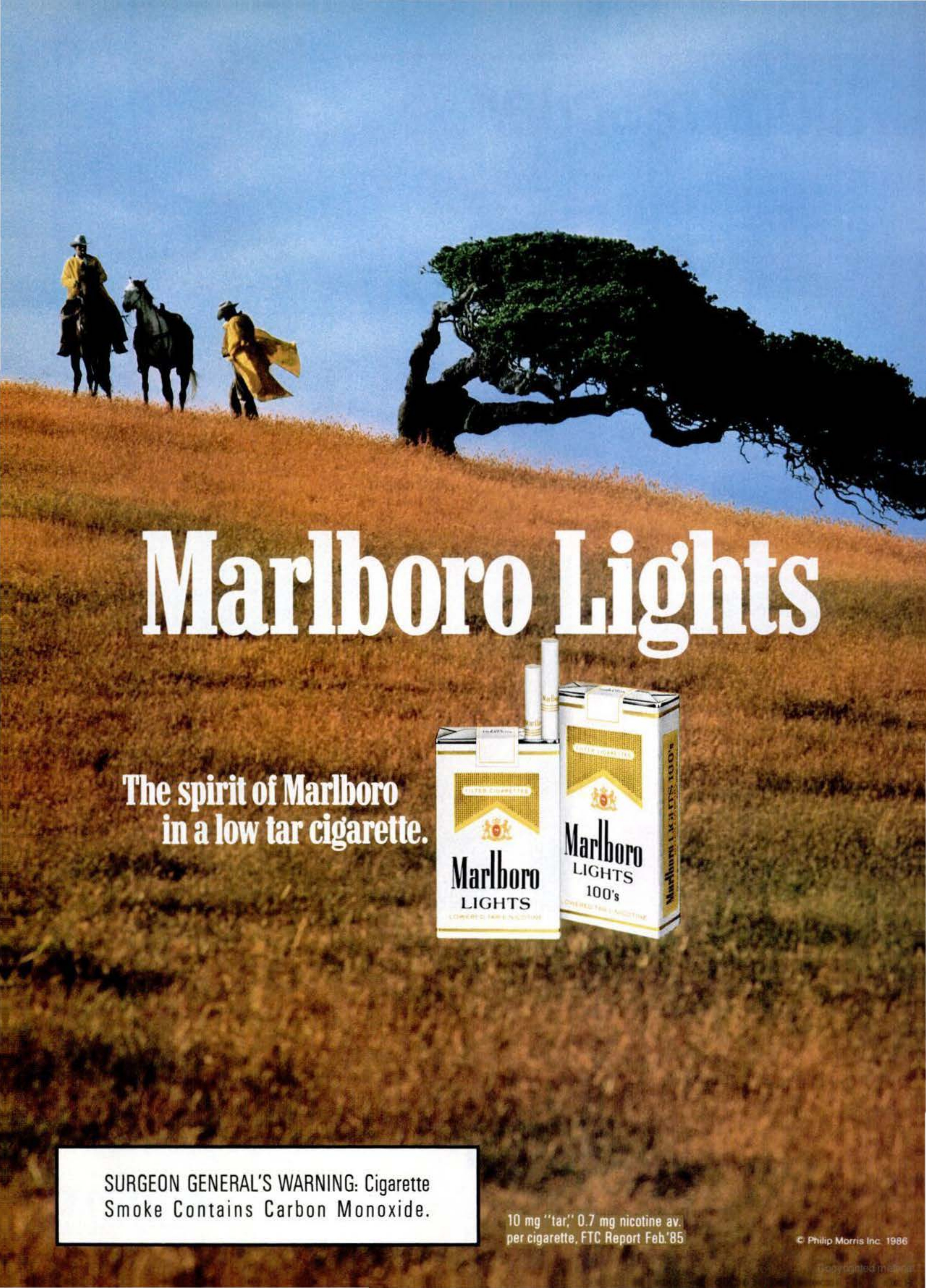
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What's News

Two-stroke in Ford's future?

Ralph T. Sarich, the innovative Australian inventor of a new two-stroke engine technology ["Can the Two-Stroke Make It This Time?" Feb. '87] may have hit the big time. Ford has signed a nonexclusive licensing agreement that gives it the right to use the advanced, stratified-charge two-stroke in its products. The two-stroke engine produces roughly twice as much power per displacement as a four-stroke engine. Ford has been testing the two-stroke in an Escort—the type of car that's considered the strongest candidate for a two-stroke. However, it's unlikely that Ford will complete its testing of the new engine in less than five years and offer its first two-stroke before the mid-'90s.

Meanwhile Sarich is offering the two-stroke engine to other auto makers in the United States, Europe, and Japan. General Motors has tested a Sarich prototype in an Opel Kadett and is known to be seriously interested in the engine.

The power of horsepower

Remember the long gas lines during the two oil boycotts in the 1970s? Remember the great swing by manufacturers to more-fuel-efficient engines and smaller cars in reaction to the gas shortages? As the 1989 models start to roll out of dealer showrooms, it would seem that much of that shock has become a dim memory. Certainly cars and light trucks produced today are more fuel efficient than those from the early and mid-'70s. In fact, some of today's vehicles get more than twice the mileage the older vehicles got. But clearly the urgency for ever more miles per gallon is waning, and car buyers in increasing numbers are opting for higher-horsepower vehicles capable of higher speeds. In fact, there are definite signs of a new horsepower race. Two symbols of this new urge for speed are shown on our cover this month: the Chevrolet Corvette 32-valve V8 and the Ford/Yamaha 24-valve V6 for a special high-performance Taurus. Both engines are able to produce an

incredible amount of horsepower per liter and seem to take advantage of every trick the car makers have learned about combustion engineering. For specific details see Dan McCosh's report, "Horsepower!"

Does all this mean that fuel economy doesn't matter anymore? The answer in my view is that fuel economy still matters to most drivers, but to a small, passionate few, power conquers all.

Last of the diesels

Another rapidly vanishing symbol of the fuel shortages is the diesel engine. During the 1970s and early 1980s, diesels were in high demand because of their fuel economy. During the 1982 model year, Daimler-Benz sold four diesel-powered cars for every gas-powered one. Detroit, which had never done much diesel-engine development for cars, imported diesels from Japan and Europe and tried hard to match the diesel offerings of imports. Now all that is history. In fact, for 1989 there will be only one diesel-powered passenger car offered in the United States—the Mercedes 190.

El Niño and global warming

Last summer's unusually high temperatures spurred much speculation that the torrid spell was related to the greenhouse effect predicted by some scientists. The greenhouse effect is a global warming trend caused by an increasing volume of carbon dioxide and other gases in the atmosphere ["The Carbon Dioxide Dilemma," Feb. '82]. The scorching atmosphere of Venus is the classic so-called "runaway" greenhouse environment.

But a researcher at the University of Colorado at Boulder's Cooperative Institute for Research in Environmental Sciences suggests two El Niño events in 1982 and 1986 ["Solving the Puzzle of El Niño," Sept. '86] may have caused last summer's record high temperatures. And, says researcher George Kiladis, an "anti-El Niño event"—a cooling of the tropical Pacific—will most likely cause a drop in

the global temperatures next year.

"I'm suggesting that part of the global warming we've seen might be due to El Niño and not carbon dioxide because we haven't had an anti-El Niño since 1975," says Kiladis. "I'm not saying there's no greenhouse effect, but I don't know how you can say the drought this year is from carbon dioxide but other droughts weren't."

Kiladis also points out that models of greenhouse warming say Earth's temperature should climb faster near the poles than near the equator. But most recent global warming has occurred in the tropics.

"We are looking for a pretty good anti-El Niño in 1988-'89," Kiladis says. "If someone asked me what the winter would be like in central Canada, I'd say it probably will have a colder than normal winter. The southeastern United States is another place there's a pretty good signal. I'd expect a warm winter there." The accuracy of such predictions? About 75 percent, Kiladis says.

Probing muscle fatigue

University of California Medical Center, San Francisco, researchers are using the magnetism and radio waves of magnetic-resonance spectroscopy (MRS) to find the chemical reasons muscles get tired ["Sharpest Look Yet Inside the Body," June]. The non-invasive technique may yield secrets that could benefit athletes, musicians, and even victims of multiple sclerosis and muscular dystrophy. MRS allows researchers to ferret out the chemical makeup of muscles—something scientists could only accomplish by biopsies. MRS helps researchers create chemical "maps" of muscles that can be viewed on a cathode-ray tube. One major finding is that tired muscles build up large amounts of phosphate. Dr. Robert Miller, one of the researchers, says, "Ours is the first work to suggest a role for phosphate in human fatigue."

Herbert Shulman
Editor

How does it feel to hover in the air like a hummingbird and then lightly touch down? Take a spin in a Harrier jump jet with a **POPULAR SCIENCE** editor and find out. The British Aerospace Harrier made its mark during the Falklands War, when a British force equipped with the unique STO/VL strike fighters recaptured the disputed archipelago. Now redesigned by McDonnell Douglas into a more capable aircraft, the Anglo-American AV-8B Advanced Harrier II gives U.S. Marine Corps aviators unparalleled flexibility in mounting attacks on enemy ground troops and fighter aircraft.

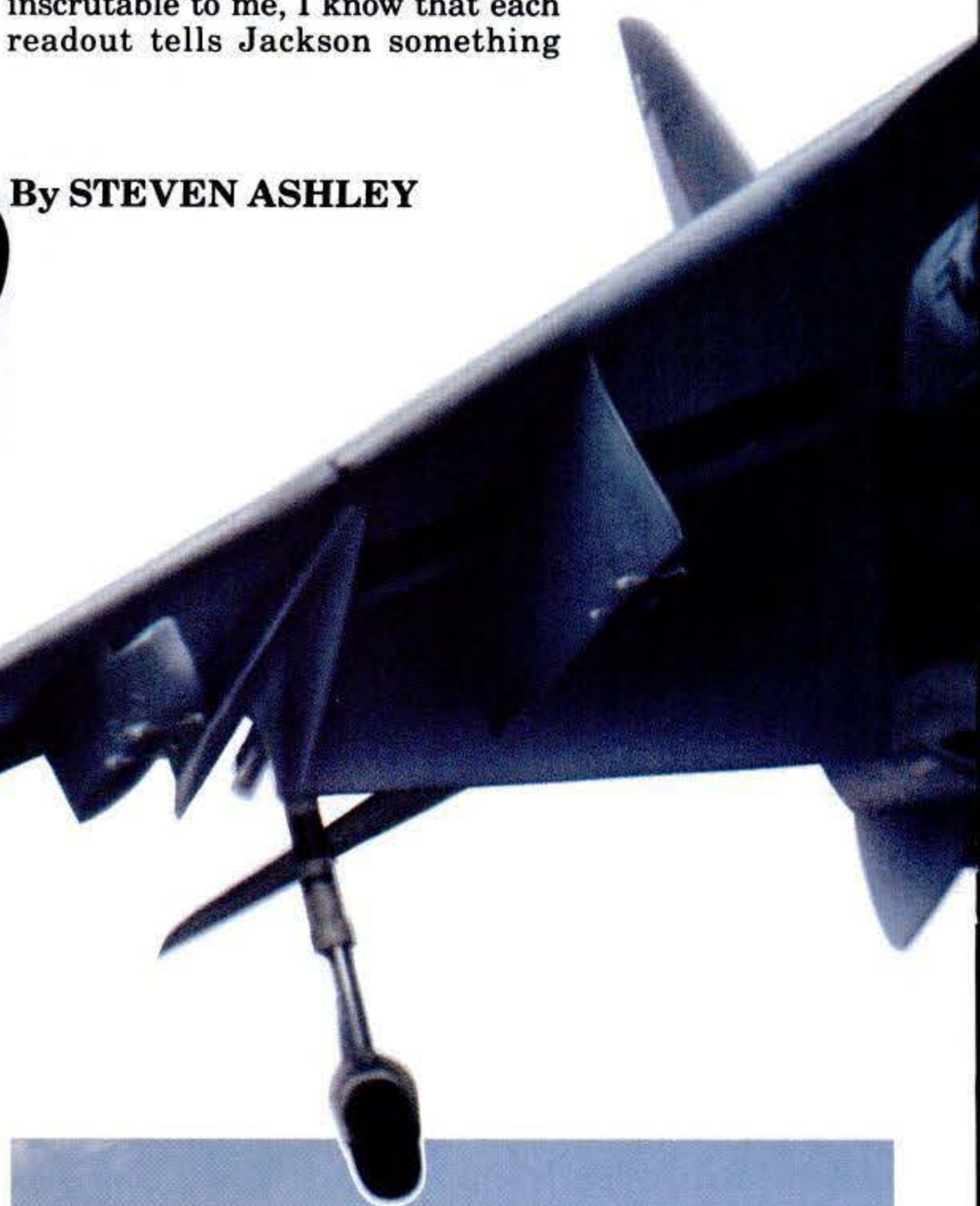
This is no air show, Steve. It's a combat capability demonstration." Even through the helmet, the intercom's squawk barely cuts through the scream of the 21,450-pound-thrust turbine spinning mere feet behind my ejection seat. I reach down to turn up the volume. "Our mission is to bomb a target ship out in Chesapeake Bay."

Unseen in his cockpit in front of me, McDonnell Douglas chief production test pilot Jackie Jackson continues the disembodied monologue: "Once I complete the engine check, we're going to do an STO—a short takeoff, a roll of maybe five hundred feet or so—just as if we were carrying a full load of external stores—bombs, missiles, fuel tanks. You can follow along with me on the multipurpose display."

The piercing whine grows louder as Jackson, a jovial ruddy-visaged former Marine Harrier pilot, punches up the throttle and the huge vectored-thrust turbofan spools up. Meanwhile, the left cathode-ray tube (CRT) on the instrument panel comes to life and starts paging fitfully through flashing columns of emerald numbers. Though inscrutable to me, I know that each readout tells Jackson something

By **STEVEN ASHLEY**

JUMP JET



about how the Rolls-Royce Pegasus 11 jet engine is running.

Out beyond the dark-tinted helmet visor, the rubber oxygen mask, and the big bubble canopy overhead, the low brick buildings of Quantico (Va.) Marine Corps Base squat below dun-colored clouds. No other airplanes are visible. The runway is too short, Jackson had told me earlier. Only helicopters here, including, notably, the president's pristine Marine chopper limos. But the strip is not too short



POPULAR SCIENCE editor Steve Ashley (above) boards the two-place TAV-8B Advanced Harrier II trainer. The Harrier II in the photo at left demonstrates hovering on jet exhaust. The sequence of three photos bottom left shows test pilot Jackie Jackson landing the Harrier II trainer, with author Ashley in the back seat, on a helicopter pad.

for what we're riding—a two-seat training version of the Harrier II jump jet, the world's most advanced short take-off and vertical landing (STO/VL) aircraft.

The green engine display slows its blinking and the intercom squawks once more, "OK. You all set?"

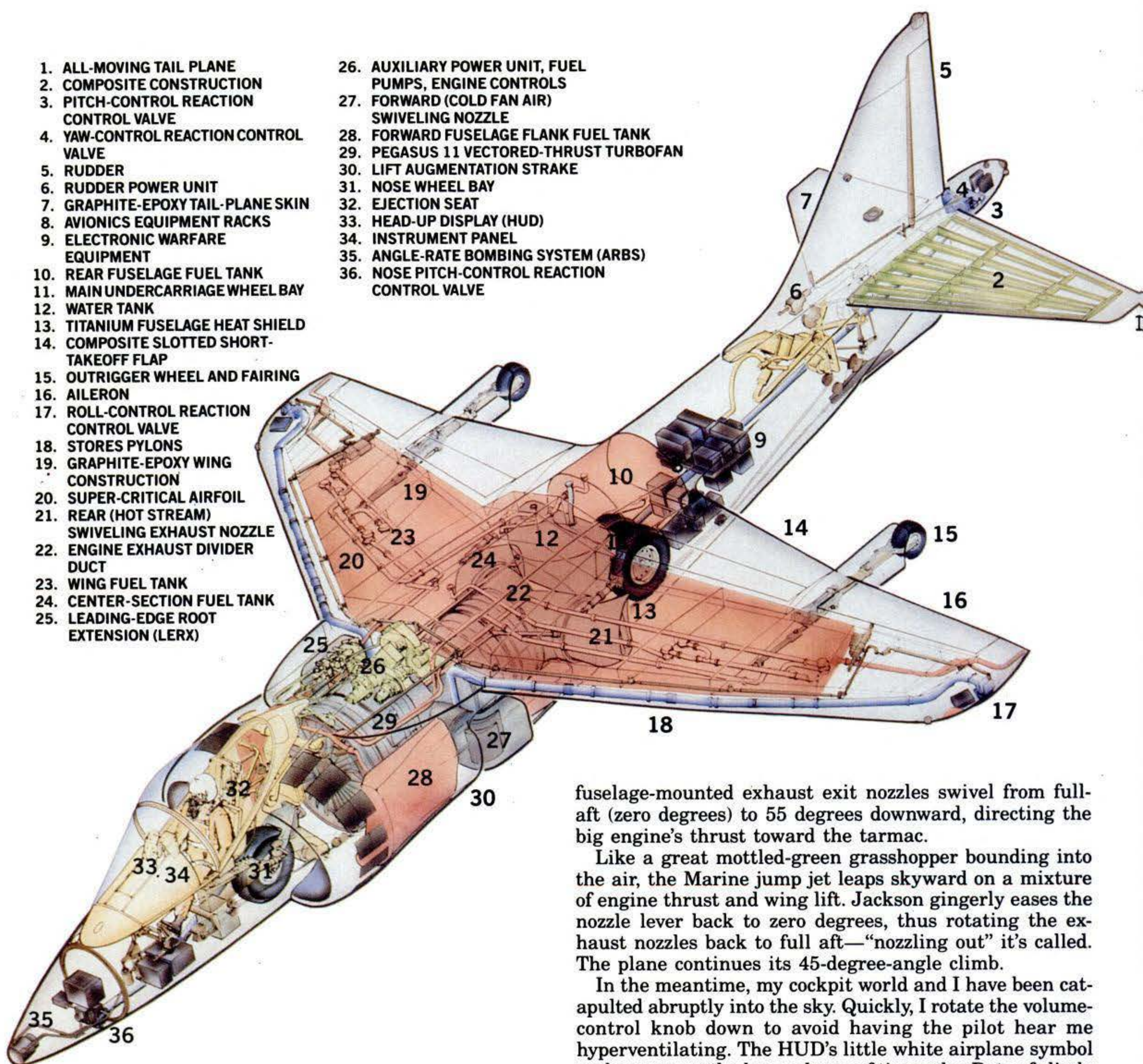
Already, the butterflies are doing figure eights in my gut and sweat pours from every pore. Funny... strapping in only minutes before clad in my fatigue-green flight suit, webbed chute harness, inflatable g-suit leggings, crash helmet, and mask, I imagined myself a medieval armored knight mounting his steed for a joust. Now I feel more like a greenhorn rodeo cowboy straddling his first bucking bronco just before the gate swings open.

For a moment I survey the cluttered bathtub of the back-seat cockpit. It's chock full of switches, buttons, levers, pedals—most of which I dare not touch. I give especially wide berth to the engine throttle lever and the knobbed exhaust nozzle angle lever near my left hand, and even wider berth to the yellow-and-black-striped ejection-seat trigger and control stick that protrude between my outstretched legs.

My eyes focus on the head-up display (HUD)—the graphics data screen that's superimposed on the wind screen. It's like looking through your car's windshield and seeing

Continued





1. ALL-MOVING TAIL PLANE
2. COMPOSITE CONSTRUCTION
3. PITCH-CONTROL REACTION CONTROL VALVE
4. YAW-CONTROL REACTION CONTROL VALVE
5. RUDDER
6. RUDDER POWER UNIT
7. GRAPHITE-EPOXY TAIL-PLANE SKIN
8. AVIONICS EQUIPMENT RACKS
9. ELECTRONIC WARFARE EQUIPMENT
10. REAR FUSELAGE FUEL TANK
11. MAIN UNDERCARRIAGE WHEEL BAY
12. WATER TANK
13. TITANIUM FUSELAGE HEAT SHIELD
14. COMPOSITE SLOTTED SHORT-TAKEOFF FLAP
15. OUTRIGGER WHEEL AND FAIRING
16. AILERON
17. ROLL-CONTROL REACTION CONTROL VALVE
18. STORES PYLONS
19. GRAPHITE-EPOXY WING CONSTRUCTION
20. SUPER-CRITICAL AIRFOIL
21. REAR (HOT STREAM) SWIVELING EXHAUST NOZZLE
22. ENGINE EXHAUST DIVIDER DUCT
23. WING FUEL TANK
24. CENTER-SECTION FUEL TANK
25. LEADING-EDGE ROOT EXTENSION (LERX)
26. AUXILIARY POWER UNIT, FUEL PUMPS, ENGINE CONTROLS
27. FORWARD (COLD FAN AIR) SWIVELING NOZZLE
28. FORWARD FUSELAGE FLANK FUEL TANK
29. PEGASUS 11 VECTORED-THRUST TURBOFAN
30. LIFT AUGMENTATION STRAKE
31. NOSE WHEEL BAY
32. EJECTION SEAT
33. HEAD-UP DISPLAY (HUD)
34. INSTRUMENT PANEL
35. ANGLE-RATE BOMBING SYSTEM (ARBS)
36. NOSE PITCH-CONTROL REACTION CONTROL VALVE

the speedometer as well as the road up ahead. In addition to digital readouts indicating airspeed, heading, altitude, rate of climb, g forces, and distance to navigation way points, the holographlike image shows rows of tic marks Jackson calls a flight path/pitch ladder. There's a small white airplane symbol—he calls it the velocity vector—in the center. It reminds me of a video-game screen... except that this game is for real.

Emerging from my split-second reverie, I manage to respond, dredging up my best Chuck Yeager-imitation drawl: "All set. Let's go."

"OK. Here we go!" the squawk replies. I grab for the lip of the cockpit's side walls.

Up front, Jackson makes a final check to see whether the Harrier's oversize and slotted high-lift STO wing flaps are in position. Then he simultaneously releases the brake and slams his throttle lever forward to full power. With a start, the Harrier accelerates down the runway, forcing me into my seat. When the HUD's airspeed indicator reads 83 knots (as slow as some Cessnas, he notes), Jackson pops the nozzle angle lever to the preset STO stop position and pulls back on the control stick. In unison, four

fuselage-mounted exhaust exit nozzles swivel from full-aft (zero degrees) to 55 degrees downward, directing the big engine's thrust toward the tarmac.

Like a great mottled-green grasshopper bounding into the air, the Marine jump jet leaps skyward on a mixture of engine thrust and wing lift. Jackson gingerly eases the nozzle lever back to zero degrees, thus rotating the exhaust nozzles back to full aft—"nozzling out" it's called. The plane continues its 45-degree-angle climb.

In the meantime, my cockpit world and I have been catapulted abruptly into the sky. Quickly, I rotate the volume-control knob down to avoid having the pilot hear me hyperventilating. The HUD's little white airplane symbol rushes up past the long column of tic marks. Rate of climb: 12,000 feet per minute. Plastered back into the seat as I am, there's not much else to do besides hold on and watch. And the view through the raised cockpit's domed canopy is breathtaking. Visibility is excellent; it's almost as if you're flying without an airplane around you.

In a half minute the plane breaks through the cloud cover and into dazzling sunlight. Jackson levels off. Looking down, I can still see the airfield about a mile below. Some escalator ride, I decide. Relaxing a bit, I realize that I've got a death grip on the cockpit walls. Jackson checks in while I work to disengage my cramped hands: "You know, Steve, no other airplane in the world can take off like that... Steve? You OK...?"

In the early 1980s the U.S. Marine Corps embarked on a \$4.5-billion program to purchase over 300 AV-8B Advanced Harrier IIs from the joint manufacturers, McDonnell Douglas Corp. and British Aerospace Ltd. It would like to have more. The ability of this second-generation STO/VL bomb truck to get aloft from a short (less than 1,000-foot-long) airfield, deliver up to 9,200 pounds of ordinance with extreme accuracy, and then land vertically on an unimproved forward site for rearming and refueling makes it valu-

able to the Corps for rapid-response close air support of ground troops.

A revolution in aviation since it first flew in 1966, the original British Aerospace Harrier jump jet, the first operational STO/VL strike fighter, earned its wings during the 1982 Falklands War. Exploiting its unique ability to operate from small aircraft carriers and container ships like a helicopter, it became "the hero of the Falklands." During those years the Marine Corps flew U.S.-owned Harriers under the designation AV-8A.

Its successor, the AV-8B Advanced Harrier II bears more than a passing resemblance to its famous forebear: It shares the high-mounted and drooping swept wings; the downward-canted tail planes; the big body-hugging air intakes; the four swiveling engine exhaust nozzles tucked under the wings; the low-speed-maneuver reaction-control jets at the wingtips, nose, and tail; the bicyclelike undercarriage with the stalky outrigger wheel units trailing the wings; and the odd, nose-up crouch of the aircraft when on the ground.

But, in fact, almost everything on the plane is new and different. "The AV-8B looks a lot like the original Harrier and it uses the same operating fundamentals," says Ed Harper, retired vice president and general manager for the McDonnell Douglas Harrier II program. "It just uses them a lot better." As such, the Harrier II is a happy compromise, experts say, taking a sound fundamental design and adding a quarter century of technological progress and a decade and a half of operating experience. The new aircraft can carry more weapons, fly them farther, and deliver them more accurately.

There are many improvements. Graphite-epoxy composites have been used in the wings, parts of the fuselage, and tail to save weight without compromising strength and fatigue resistance. For instance, the composite wing weighs 330 pounds less than an all-metal wing. The Harrier II sports a larger wing with a super-critical airfoil shape that accommodates more fuel inside (the original Harrier was notoriously short legged) as well as more pylons for weapons and fuel. Lift improvement devices—underbody air fences that form a "box"—capture reflected thrust to augment lift for vertical takeoff and landing. The forward fuselage was redesigned for greater visibility, and the cockpit has the latest in avionics systems. The engine air intakes were reconfigured to provide more takeoff thrust, more efficient cruising, and allow the engine to run cooler and so last longer. A highly accurate bombing system was incorporated. Leading-edge root extensions were installed, which add to the AV-8B's ability to make tight turns, and thus to its ability to maneuver in dogfights. An on-board oxygen generating system, a "molecular sieve" that strains oxygen from engine exhaust, was added to eliminate the weight of oxygen tanks.

Trundling out at 250 knots over the Chesapeake on a course for the restricted area at the Naval Air Test Center near Patuxent River, Md., Jackson leads me through what he calls the Harrier's "Star Wars" cockpit avionics. Communications, navigation, weapons, and other key controls are all on one touch pad on the center console. What was intimidating mere minutes before turns out to be relatively simple: Touch a button to bring up a menu display on a CRT screen. Select a menu item, then you

press some other buttons to manipulate the chosen data.

It's a big change over the original, he tells me: "For example, in the old AV-8A Marine pilots used maps, compasses, and stopwatches. That's all gone now. Push a button, and the computerized inertial navigation system tells the pilot his headings, his distance to selected way points, and his time to the target."

Hold that stick

Now that I'm just starting to get comfortable with flying, Jackson decides to liven things up a bit: "How'd you like to take the stick?" Gulp. "Sure, what do I do?" I reply uneasily. "OK, first put your right hand on the stick and your left hand on the throttle. Now when I say, 'You've got the stick,' you say, 'I've got it,' and I'll hand it off. After that, just keep her steady with real light movements on the stick. She handles like a Corvette—very responsive. Just make sure the airplane symbol in the HUD stays in the center. OK?" "OK," I answer, thinking that Jackson must be very brave to let me fly this thing.

"You've got the stick." "I've got it." Up ahead in the front cockpit, a pair of green-gloved hands reach up to the top of the canopy. Startled, I suddenly realize, *I really do have it!* A strange feeling of power comes over me: *I'm flying a \$13-million death machine across the sky!* And it's pretty easy to keep the plane on course. Move the stick a bit to the left, and the plane

moves to the left. Move it a touch forward, and the plane dips down some. The trick is to compensate for drift without overcompensating. It's altogether exhilarating. I'm hooked, line and sinker included.

While I timidly imitate Tom Cruise in *Top Gun*, Jackson lectures, "The AV-8A had a lot less lateral stability because the wing was smaller. Plus the stability augmentation system [SAS] in the A dropped off the line at two hundred fifty knots... you were flying airframe above that speed. In the AV-8B, the SAS stays on line throughout the entire flight envelope. The B is eighty percent easier to fly than the A." I recall one pilot telling me that "flying an AV-8A was like standing on a beach ball." "Would you have allowed me to fly an A like this?" I ask. "No way," comes a curt reply over the intercom.

Jackson continues the tour. "You're also demonstrating the HOTAS—hands on throttle and stick—arrangement McDonnell Douglas engineers have developed. It means that you can transmit on the radio, select your weapons and your sensors, and engage the flaps and speed brakes without ever taking your hands off the throttle and stick. That's a nice piece of technology. The pilot doesn't have to look back inside the cockpit to find a switch, for instance."

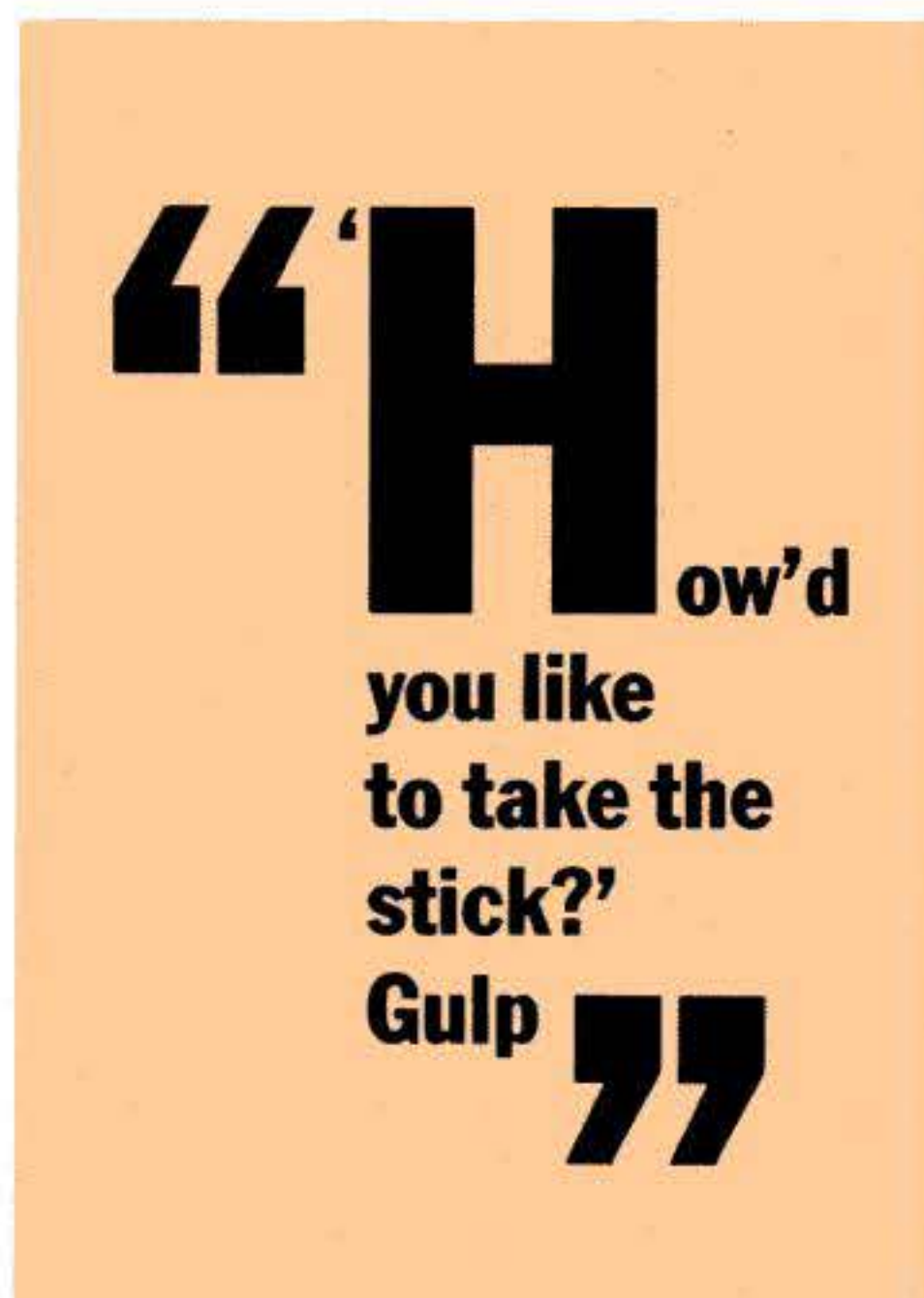
Jackson asks to reclaim the controls, so I hand them back, allowing myself a sigh of relief. But, of course, the fun's not nearly over.

G-whiz

"How about pulling some g's?" Dead air for a reply. "Don't worry, I'll take it easy, we'll build up to it," Jackson says. "Sure," I agree laconically. Girding for this latest trial, I plant myself firmly in the seat, my hands once again clutching the lip of the cockpit.

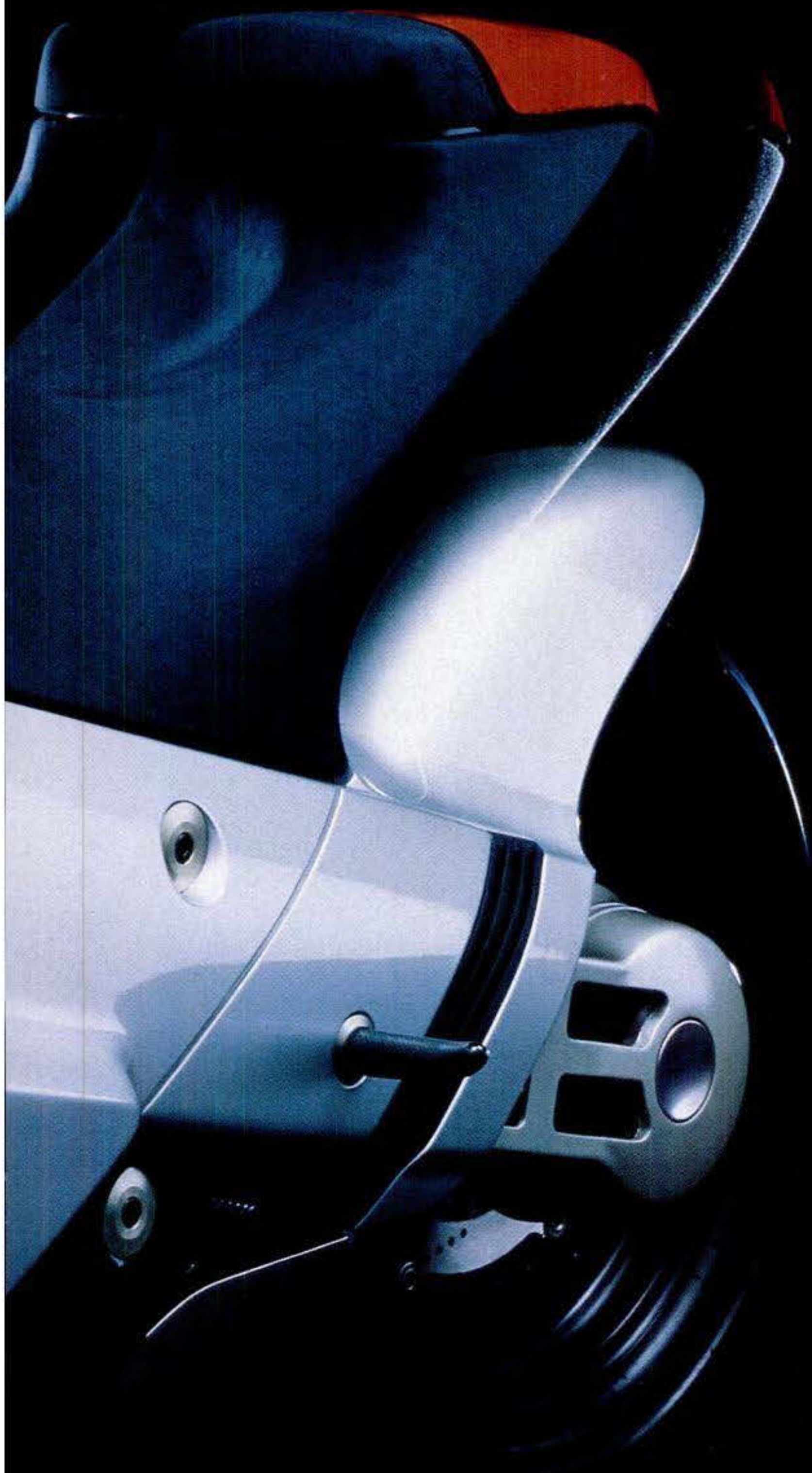
"OK, here we go." Immediately, I'm pressed into the seat.

[Continued on page 112]



2-WHEEL DRIVE!





A whole flock of all-wheel-drive cars is on the road, so why not a both-wheel-drive motorcycle?

That's part of the reasoning behind the Nuda, a new concept bike Suzuki Motor Corp. unveiled at last year's Tokyo Motor Show ["Ultimate Technocars," Feb.]. While much remains to be learned about what benefits two-wheel drive may ultimately bring to motorcycles, Suzuki's engineers feel that it does offer several. Providing power to both wheels, they believe, can enhance stability during straight-line acceleration and cornering, as well as improve traction on unpaved surfaces.

The Nuda is built around a version of Suzuki's existing GSX-R 750-cc engine that's been equipped with electronic ignition timing and fuel injection. But that's where the similarity to today's motorcycles ends. Instead of connecting to a chain or rear-wheel drive shaft, the transverse four-cylinder engine's output shaft drives a bevel gear which in turn powers two counterrotating drive shafts—one leading to each wheel. Spinning the drive shafts in opposite directions cancels out their torque reactions, say Suzuki engineers.

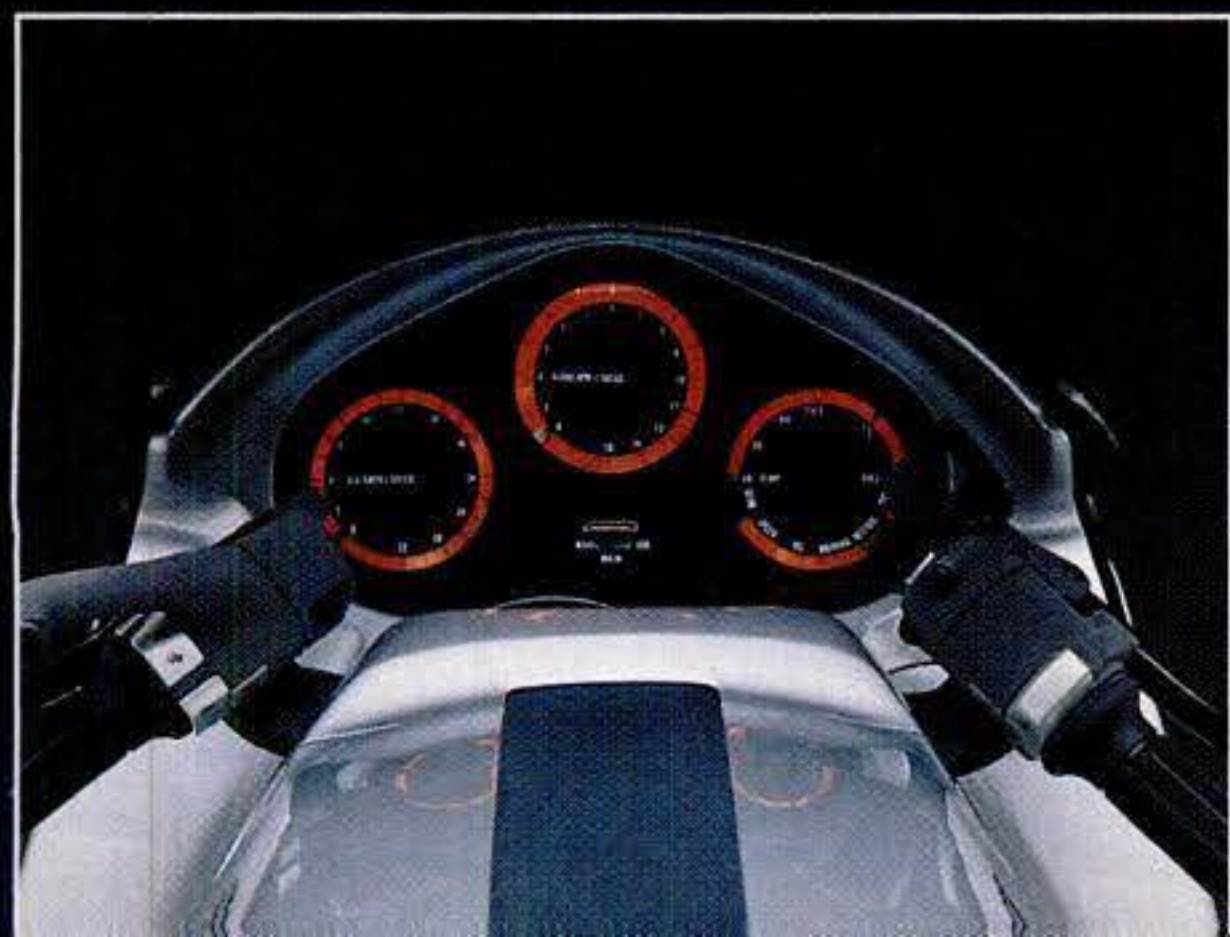
Potential tire-scrubbing problems caused by the two wheels rotating at slightly different speeds in turns are overcome by a viscous coupling located between the engine and front drive shaft. (Several all-wheel-drive cars use similar limited-slip devices.)

The Nuda's one-sided swing-arm-type front suspension encloses the drive shaft and locates the front-drive hardware inside the deeply dished (concave) carbon-fiber wheel. The suspension arm runs along the left side of the bike and attaches to a kingpin upon which the wheel pivots for steering. Suzuki's previous FalcoRustyco show bike ["Futurebike," Feb. '87] used a similar front-end arrangement to avoid diving during braking. The Nuda's front brake is novel in that its disc attaches to the wheel rim—rather than to the hub—with the brake caliper pinching the disc from the disc's inner diameter.

When the Nuda banks into a turn, the seat swings slightly to the right or left to make it easier for the rider to shift his weight for good balance. The headlight cooperates by altering its beam direction to track the inside of a turn, improving illumination and reducing glare for oncoming vehicles.

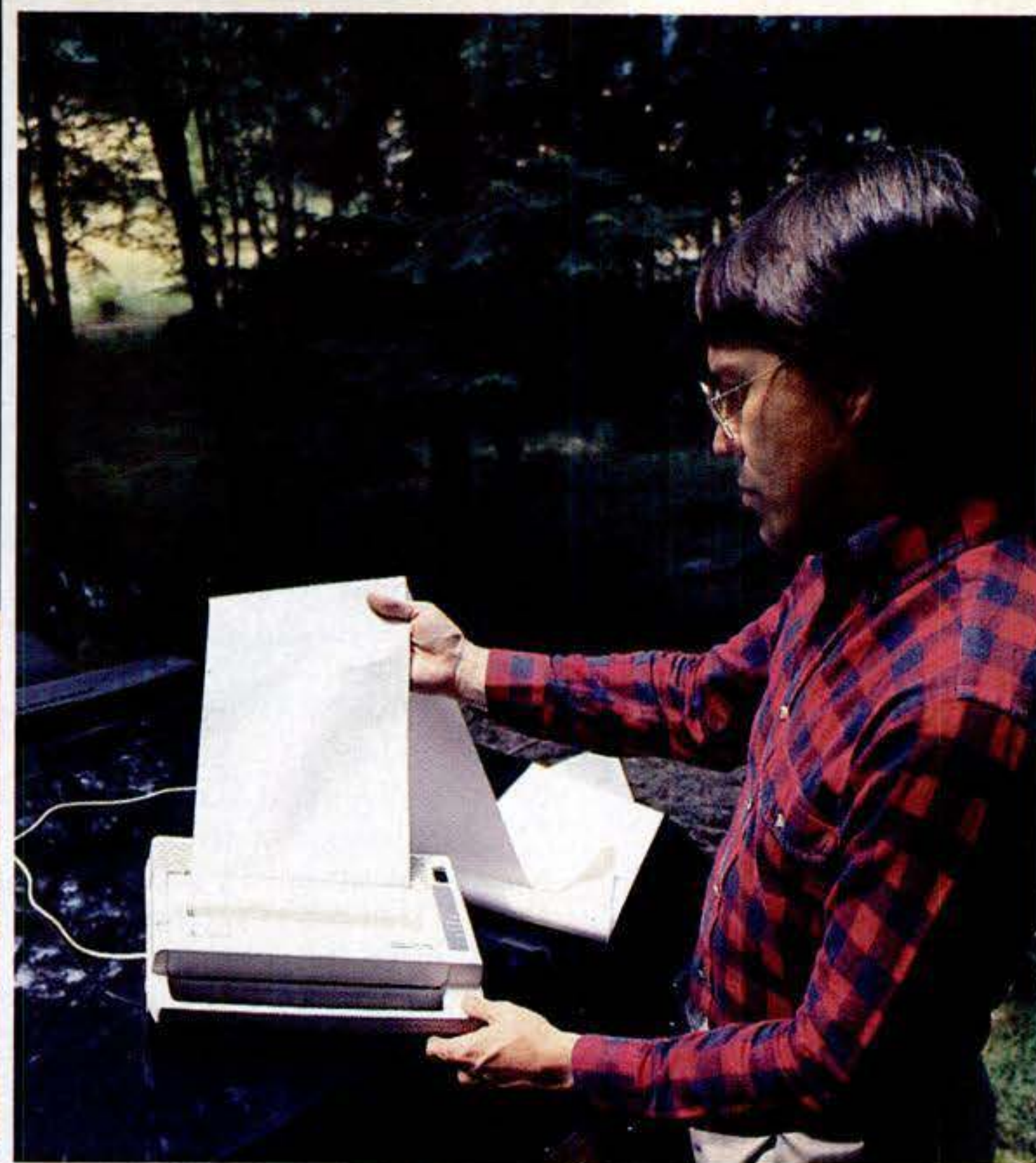
The bike's monocoque "body" consists of two half shells built up from carbon-fiber honeycomb material; the front and rear inboard shock absorbers reside underneath. A slot in the instrument panel (inset below) accepts a credit-card-type ignition key that initiates automatic suspension adjustments tailored to the rider's weight.

With its second show bike in as many years, Suzuki provides another tantalizing peek at where motorcycle design may be headed. But that name! Only the Japanese could come up with a cycle that uses "the beautiful nude body as the motif of its design." —*Stuart F. Brown*



Fax phones, such as this Canon 20, are not much larger than a standard desk telephone. Documents can be received, copied, or sent. Phone calls are made with all the standard features, like instant memory dialing. Portable fax machines, such as the Cobra Print Phone at right, work anywhere a phone—including a cellular phone—is available.





Skip the mailman: Send letters, notes, pictures, and drawings anywhere instantly for the price of a phone call. New ways to “read” your document make facsimile—fax—machines small, fast, easy to operate, and usable in your home, office, or even your car.

Don't mail it... FAX IT

By DAVID ELRICH

Photos by John B. Carnett

Mail it?” Ralph Pugliese, manager of a medical testing lab in New Jersey, looks at me incredulously. “Watch this.”

He gingerly reaches under a ream of papers piled on his desk and lifts them to expose a book-size box. “Forget the mail,” he says. “Forget the computer. This little box has changed the way I work.” Pugliese finds a scrap of paper that’s scribbled with quick revisions he’d like to see on a report, pushes it into the box, and presses a button. I hear a slight whirring sound, and in seconds the paper is consumed.

“My colleague across town is now looking at my notes and drawings,” says Pugliese with a smile. Then he laughs. “You’d still be hunting for a stamp.”

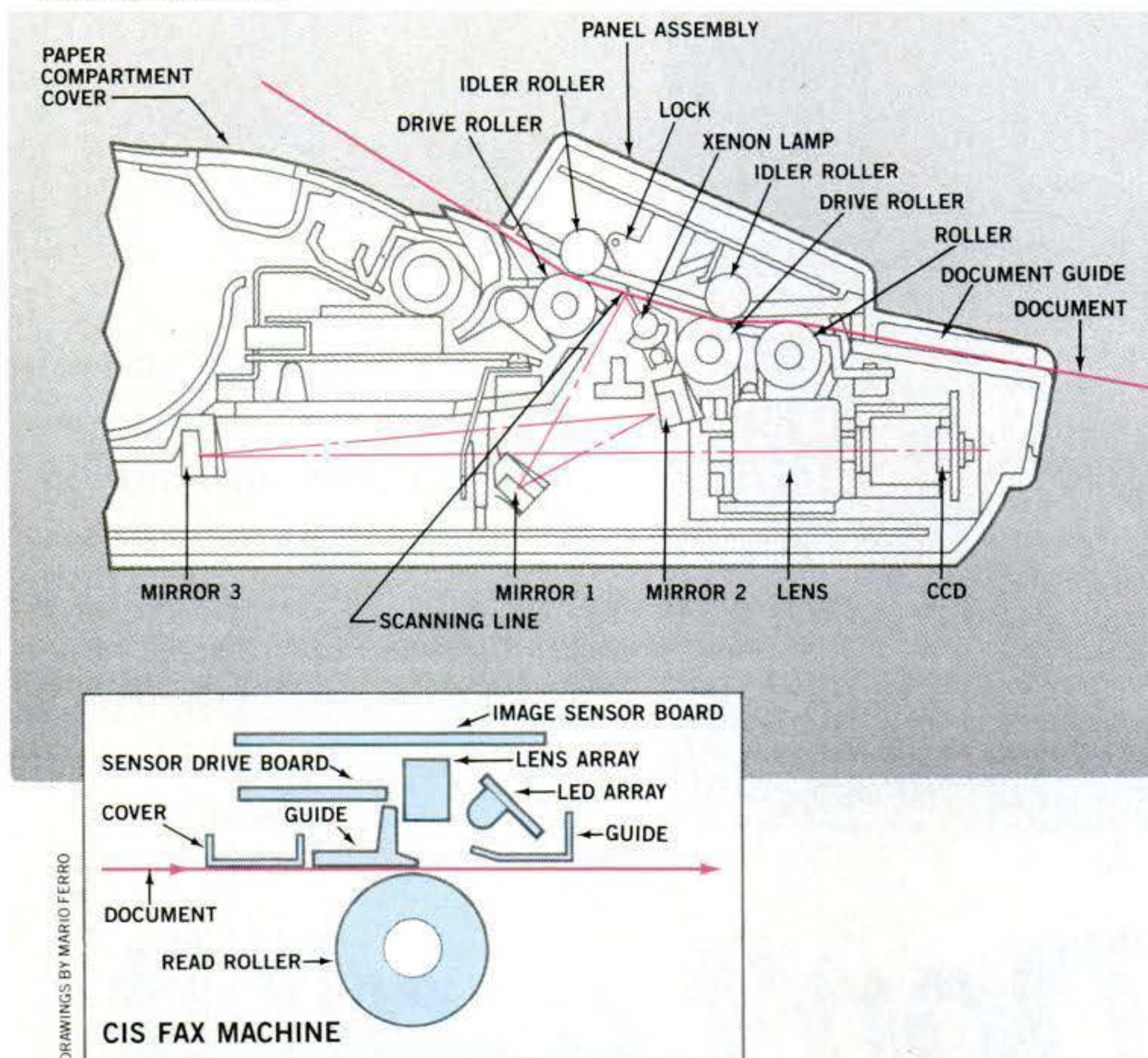
Pugliese’s light-speed delivery service comes from a facsimile—fax—machine, a clever box that sends documents from one place to another via standard phone lines. Put a piece of paper in your fax at one end, and the receiving fax machine makes a duplicate of it at the other end. Time? “Less than thirty seconds,” says Pugliese. “That even makes overnight mail seem silly.” And it makes overnight prices ridiculous. Because fax machines use the telephone line, the delivery cost—across town or across the country—is the same as the price of a phone call.

A new idea? Hardly. In 1842 Scottish inventor Alexander Bain theorized

Continued

Plug-in fax circuit board from The Complete PC (shown above) sends and receives fax information using your personal computer. Text or graphics files can be sent. Incoming documents can be stored, printed, or displayed on the screen.

CCD FAX MACHINE



CCD fax system (top) requires a larger enclosure to provide the correct distances between light source, mirrors, lens, and CCD. Above, the CIS system uses a row of LEDs as a light source. Ordinarily, the reflected light is routed to detectors via fiber optics. The Canon model shown places a single lens and detector up at the LED array.

the first fax machine. Over 100 years later, a 1947 issue of *POPULAR SCIENCE* explained how a refrigerator-size fax system could send and receive pictures via radio. But while the basic idea has been the same over the years, only recently have fax machines begun to be accepted as desk-top partners. Why?

Bulky optical devices in earlier machines have been replaced by thumbnail-size CCDs (charge-coupled devices) to "read" documents; critically aligned mechanics have been made obsolete by light-carrying fiber optics; and digital electronics coupled with new modem technology help the machines work at high speeds over a variety of telecommunications networks—including cellular.

The result is a fast, easy-to-use tool for your home or office (or car) that can change the way you do business.

Fax fix

"There are two types of scanning in facsimile machines," says Ron Roberge, marketing manager for the facsimile division of Mitsubishi, "CCD and contact image sensing [CIS]."

CCD machines use the tiny CCD imager found in camcorders to "see" the paper. "A fluorescent tube illumi-

nates the sheet," says Roberge. "Its image is picked up by an array of mirrors that bounce it into a lens and onto the surface of the CCD." Electronics in the fax scan the CCD, converting the image's light and dark picture elements—pixels—into representative voltages used for transmission.

The CCD fax eliminates much of the scanning mechanics once needed for the earlier photo-optical machines, and is the most common type now available. But it's still not as compact as it could be. "The optical path between the fluorescent tube, mirrors, and lens must be at a set distance," says Roberge, "so the unit is bulkier than one using contact image sensing."

Developed by Mitsubishi and Matsushita, CIS uses a strip of 200 LEDs that stretches across the document. "The strip actually touches the paper," says Roberge. The light from each of the LEDs is reflected by a single mirror into a matching fiber-optic link that carries the light to the electronics' light-detector circuitry. "There are no set distances," says Roberge. "The fiber-optic cable can be twisted, bent, and formed in any shape for a compact design." (Canon does it a bit differently; see drawing.)

Result: "The box doesn't get in my way," says Pugliese, as he shoves his tiny fax into a corner of his desk. And prices, while presently starting at about \$1,000, are expected to plummet (some say to as low as \$300 within a year) once all the new technology is used in mass production.

Faster fax

"It sets up in minutes," explains Michael Keating, senior account executive for Porter/Novelli Public Relations in Chicago. "You just plug in the machine's AC cord and modular phone cable."

Using a fax is just as easy. Dial the number of the receiving fax, place a document in your machine, and press the start button. From then on, the two faxes do the work.

"When a major corporation has news we can notify the press immediately," says Keating. "There's no time lag, and the information is as up to the minute as possible."

As Keating's press release is read by his fax, the document's image is converted into tones for analog phone-line transmission in the same way a computer's data are converted by a modem. At the receiving end, the tones are decoded back into pixels. Depending on the fax model, an internal thermal print head (for use with heat-sensitive paper) or a thermal-transfer print head (for standard bond paper) reprints his release.

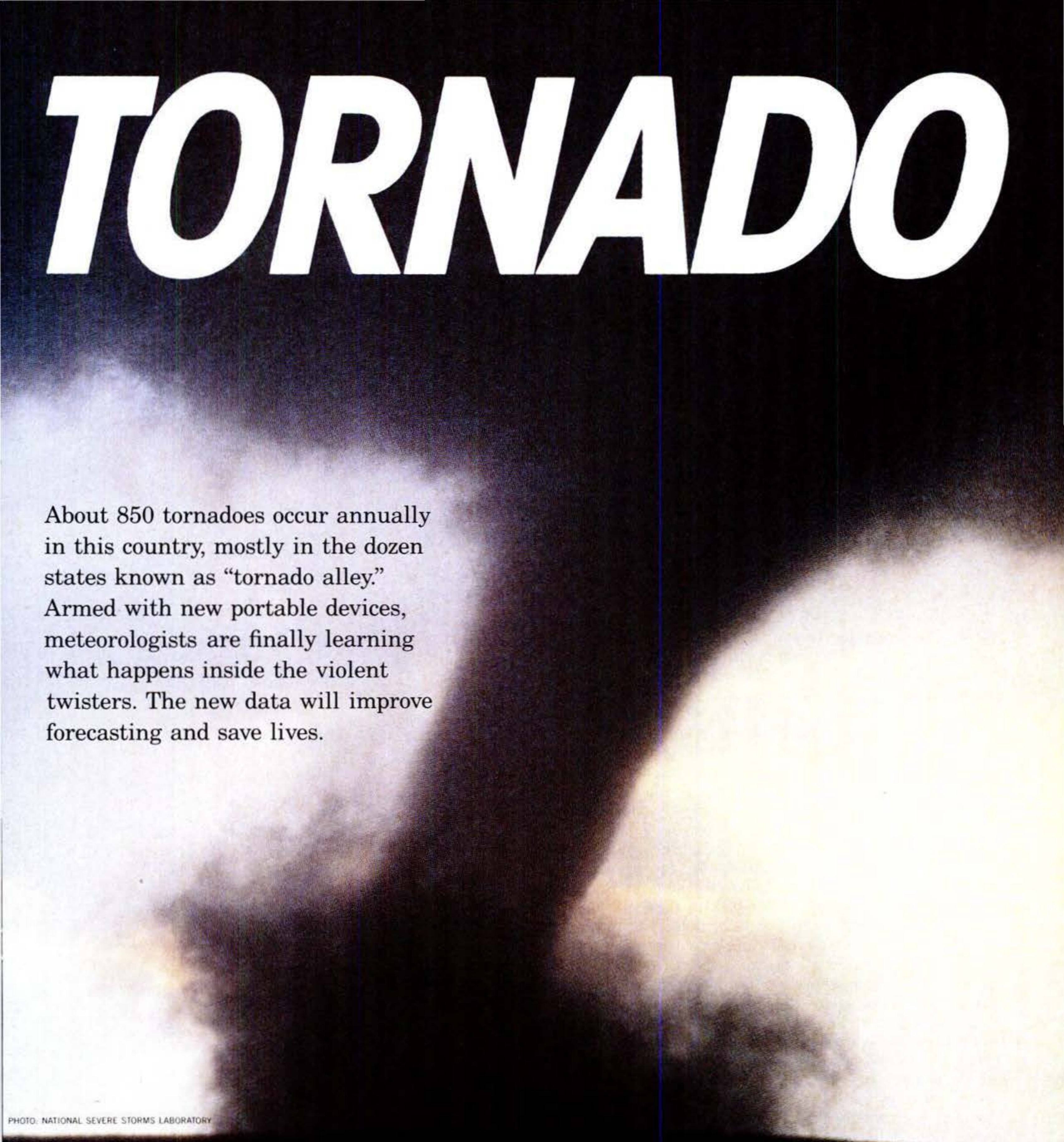
The speed by which a document is sent varies. Like a computer modem, fax machines are rated in bits per second (bps). The new fax machines rival the latest modem models working at up to 9,600 bps. At that speed, the minimum amount of data a fax needs to reproduce a picture could be sent in about 12 seconds—and some manufacturers make that claim. "But don't believe it," warns Toshiba's telecommunications systems marketing manager, David Bergevin. "The numbers are like EPA figures for gas mileage," he says. "It only happens under optimum conditions, which are a rarity."

Optimum conditions means no line noise (unlikely) and both sending and receiving machines working at the higher 9,600-bps speed. (Most new machines, called Group 3, use this speed, but many Group 2 machines, which work from 2,400 to 7,200 bps, are in use.)

Speed can be affected in other ways too. Julia Shepps owns a small ad agency in New York, and she regularly faxes ads between clients and newspapers. "From an eight-hour turnaround, it's become just five minutes," she says. "I couldn't be without it,"

[Continued on page 101]

TORNADO



About 850 tornadoes occur annually in this country, mostly in the dozen states known as "tornado alley."

Armed with new portable devices, meteorologists are finally learning what happens inside the violent twisters. The new data will improve forecasting and save lives.

PHOTO: NATIONAL SEVERE STORMS LABORATORY

By GODE DAVIS

The author, a meteorologist, is an associate member of the American Meteorological Society.

As dusk approached on May 8, 1986, Randy Hogan stood in his front yard in Edmond, Okla. He peered anxiously toward the southwest and noticed what meteorologists call a wall cloud, a dramatic lowering of a thunderstorm's cloud base. "It was black, ominous, and getting closer," Hogan recalls. Seconds later a sinuous funnel dropped from

the cloud to the ground—a tornado. "It was heading for our street," he says. He ran indoors and herded his family into the bathroom. "I laid the kids face down in the tub and covered them with pillows," says Hogan.

The Hogans were terrified by a low-pitched rumbling sound that seemed to surround them. A tremendous crash followed as the Hogans' roof was ripped off and a 2½-ton pickup truck was hurled into the children's bedroom. "We found the cab parked on my daughter's bed," Hogan says. A moment later

Continued



WEATHER SATELLITE

ILLUSTRATION BY DEAN ELLIS

the tornado had passed. "Here we were," he remembers, "sitting outdoors in the pouring rain in the midst of what a few moments before had been our home."

Lucky to be alive, the Hogans are survivors of a strong F3 tornado (see box, Measuring Tornadoes). Edmond, a suburb of Oklahoma City, lies in the Midwest corridor from Texas to Wisconsin, where tornadoes are most prevalent. The town is only a few miles from Norman, where researchers from the National Severe Storms Laboratory (NSSL), the University of Oklahoma, and the National Weather Service are working to improve the forecasts and warnings of severe storms.

In recent years, researchers using pursuit vans that carry portable radar equipment and sensor-equipped balloons have been able to intercept storms in the field, measuring variables they couldn't study before—like the speed of winds that are rotating inside a tornado. And in the laboratory, researchers studying simulated tornadoes are testing new ways to calculate the strength of the swirling winds. These data, when combined with information gathered by meteorologists who are monitoring storms from weather stations, should give researchers a detailed model of tornado behavior, which will help them predict the arrival of violent storms—hours in advance, perhaps. To learn how the new tools are being used, I visited the research centers in the heart of tornado country, and even went along on a tornado chase.

Born in the U.S.A.

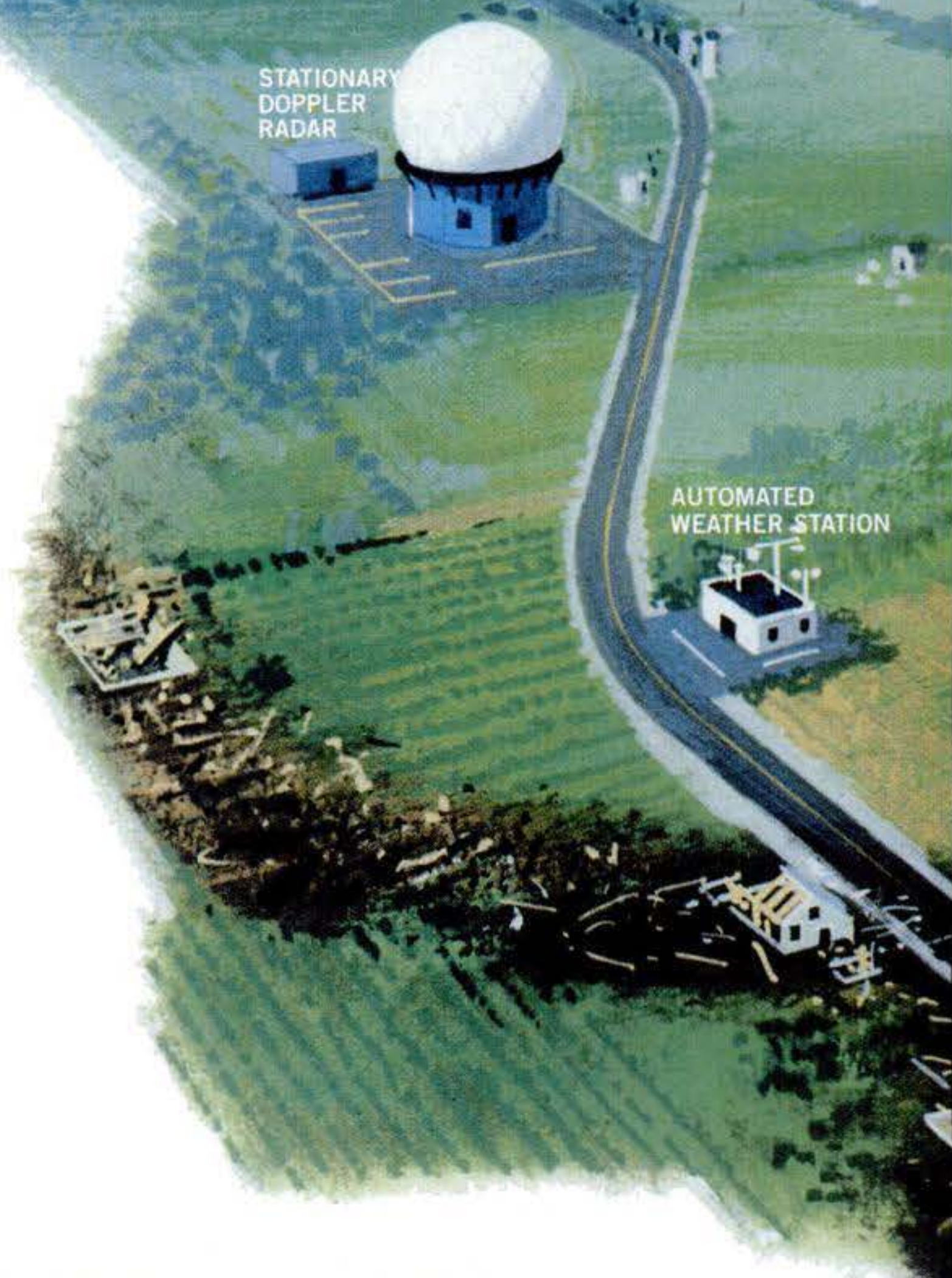
Tornadoes can strike anywhere in the United States, which has more tornadoes than any other country. (A tornado is any rapidly rotating column of air that touches the ground. In the air, it's called a funnel cloud.) Tornadoes are most apt to occur during the late afternoon and evening hours in the spring and fall, when the air is least stable.

"First there has to be a favorable area for thunderstorms to form—an unstable air mass in which the wind direction turns with height," says NSSL meteorologist Dr. Edward Brandes. "If the air is then lifted by a passing cold front or rises because of daytime heating, a mesocyclone—a

Continued

INSIDE A TORNADO

Tornadoes almost always begin with mesocyclones, severe thunderstorms containing rotating updrafts of warm air. When these updrafts occur in the relatively rain-free right rear portion of a storm, they can draw in air from cool downdrafts trailing the storm and form funnel clouds. Those that touch down become tornadoes. Sometimes suction vortices, fierce miniature twisters 30 to 100 ft. across, swirl around the main funnel. Scientists study tornadoes with satellites, stationary and mobile laboratories containing a variety of instruments, radiosondes, and Doppler radar.





RADIOSONDE
(CARRIED BY
WEATHER
BALLOON)

INTRACLOUD LIGHTNING FLASHES

DIRECTION OF STORM MOVEMENT

MESOCYCLONE

EMBRYO
CONDENSATION
FUNNEL

SINKING COLD AIR
(INTENSE DOWNDRAFTS)

SUCTION
VORTICES

STRONG ROTATING UPDRAFTS
(WARMER AIR)

RAIN AND LARGE HAIL SHIELD

PORTABLE
DOPPLER
RADAR

PROJECTILES

MOBILE
LABORATORY

DEBRIS



severe thunderstorm with a powerful rotating updraft—may develop.”

With few exceptions, tornadoes are born in mesocyclones. Once they spot a mesocyclone, forecasters know they’re dealing with a fierce storm that produces $\frac{3}{4}$ -inch-diameter hail and winds blowing at a minimum of 60 mph. Says NSSL meteorologist Doug Forsyth, “It also means there’s a fifty-fifty chance of a tornado.”

Meteorologists aren’t sure why some mesocyclones produce tornadoes and others don’t. And though they’ve learned from video recordings and direct observations that tornadoes almost always form in the right rear quadrant of a severe storm, they don’t know why. But they’ve learned a great deal since the early 1970s, when they first began chasing tornadoes across the plains with scientific instruments [Sept. ’73].

For one thing, meteorologists have learned that tornado wind speeds don’t exceed 300 mph. And they’ve discovered that although a tornado’s atmospheric pressure may be as much as 100 millibars lower than the surrounding air pressure, that isn’t enough to make a building explode. So it isn’t necessary to open your windows when a tornado approaches.

But there’s still much that meteorologists don’t understand about tornadoes. What triggers them? Is lightning a factor? Why are most tornadoes relatively weak while a few are monsters? Why do some have longer damage paths? Do wind speeds change during a tornado’s lifetime? Does a mile-wide tornado have stronger winds than a smaller tornado?

Dishing up the data

To answer these questions, tornado researchers are using Doppler radar devices, their most important tools. There are several sizes of Doppler radars, including large stationary dishes and smaller portable ones. All emit microwaves that are reflected back to a receiver by moving particles, such as water droplets or hail.

Conventional radars can detect thunderstorms, but they can’t tell meteorologists whether a storm’s winds are rotating. Doppler devices *can* identify a mesocyclone. Dopplers can also spot wind shear—sudden gusts near the ground. And vertical wind shears may indicate a likelihood of tornado development two to four hours before it occurs.

A 30-foot-diameter dish antenna on the NSSL grounds in Norman sends out 10-centimeter-wavelength microwaves. It’s housed in a hollow radome. A twin radome sits at the NSSL’s Cimarron site, 25 miles to the northwest. Finding the radomes is easy. They’re 70 feet high, 60 feet wide, and look like enormous golf balls.

Inside the radar building with Forsyth, I’m watching bright color-enhanced images of a mesocyclone on three display monitors. “The first screen tells us where the rain is falling and at what rate,” Forsyth explains. I notice a red area called a hook echo. Says Forsyth: “It depicts heavy rain and hail that’s being carried out into a thunderstorm’s dryer air, which happens because the storm is rotating.”

A second screen shows velocity. “It’s telling us whether particles are coming toward or going away from the radar,” he continues. The last screen gives an indication of turbulence.

Before forecasters began using Dopplers, they relied on reports radioed or phoned in by cooperating observers. Because some spotters were poorly trained, up to 80 percent of the tornado reports received were false alarms. All too often, lead times simply didn’t exist. “By the time hook echoes might appear on ordinary radar, the tornado already existed,” Forsyth says. “Using Dopplers, we now have up to twenty minutes lead time.”

But for most forecasters Dopplers aren’t yet available. “There are a limited number of Dopplers operating in the entire country, and most of them are smaller, five-centimeter-wavelength radars,” says meteorologist Brown.

The situation should improve with NEXRAD, or Next Generation Radar, a federal program that is supposed to replace the nation’s network of ordinary radars with 100 Dopplers during the 1990s. A second experimental network of radars, called Profilers, should also be in place by 1995. Profilers are radars specifically calibrated to measure winds in the upper atmosphere, 1 to 20 miles above some 30 sites. “In addition to having weather-balloon soundings every twelve hours, we’ll have wind profile data available every six minutes to help forecast potential severe weather episodes,” says Forsyth.

But even after NEXRAD and Profiler are operative, gaps will exist. “Many tornadoes form in isolated areas and strike tiny towns,” says Dr. Robert Davies-Jones, an NSSL meteorologist and director of the agency’s storm-intercept program. What’s needed are hundreds of automated weather modules placed in the remote areas of western states. These stations would measure weather variables like temperature, wind direction, wind speed, and atmospheric pressure; and they’d be linked to a central computer. The remote stations could detect localized wind shears, possibly indicating tornadic activity hours in advance.

A smaller version of these automated weather stations has already been used by storm-intercept teams. Called TOTO, for totable tornado observatory, the 400-pound unit can be placed directly in a tornado’s path. Dr. Howard Bluestein, a University of

Oklahoma meteorology professor who’s an avid tornado chaser, led a chase group on May 22, 1981, the afternoon TOTO was first deployed, and the same day a tornado struck Binger, Okla. “That was a monster tornado—more than a half mile wide,” recalls Bluestein. “Even from three miles away, we could hear its low-frequency roar.” A smaller tornado brushed by TOTO, which had been deposited along a likely pathway. “We got some wind measurements, close to that tornado, for the first time ever,” Bluestein says.

However, TOTO probably will be abandoned this year, or outfitted with a more stable triangular base. “It’s supposed to be able to measure wind speeds of one hundred

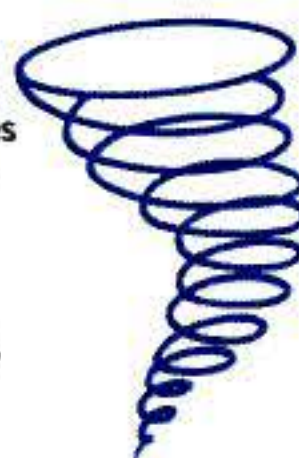
MEASURING TORNADOES

The Fujita, or F-scale (named for Dr. T. Theodore Fujita, a professor of meteorology at the University of Chicago), is the standard measure of a tornado’s relative wind strength and damage potential. The lower end of the scale can also be used to assess other types of violent winds, such as micro-downbursts and gust front phenomena. Most tornadoes are F0 or F1. Less than one percent are F4 or F5.

F0 or F1 = WEAK TORNADO

F0 (40–72 mph): Light damage. Will do some damage to chimneys, break branches off trees, push over shallow-rooted trees, and damage sign boards.

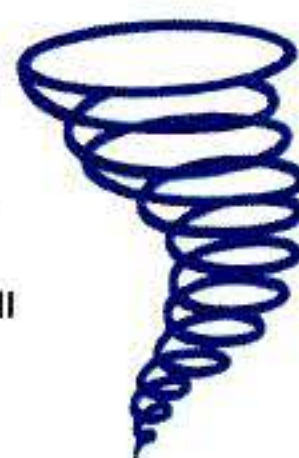
F1 (73–112 mph): Moderate damage. Will peel surface off roofs, overturn mobile homes or push them off foundations, and push moving cars off roads.



F2 or F3 = STRONG TORNADO

F2 (113–157 mph): Considerable damage. Will tear roofs off frame houses, demolish mobile homes, push over box-cars, snap or uproot large trees, and turn light objects into missiles.

F3 (158–206 mph): Severe damage. Will tear roofs and some walls off well-constructed homes, overturn trains, uproot most trees in a forest, and lift and throw heavy cars.



F4 or F5 = VIOLENT TORNADO

F4 (207–260 mph): Devastating damage. Will level well-constructed homes, blow poorly constructed buildings some distance, toss cars about, and turn heavy objects into missiles.

F5 (261–318 mph): Incredible damage. Will lift well-constructed homes off foundations and carry them considerable distances to disintegrate, send truck-size missiles flying through the air for 500 ft. or more, debark trees, and perform other amazing—and deadly—feats.—G. D.



DRAWINGS BY MITCHELL J. ALBALA



PHOTO: NATIONAL SEVERE STORMS LABORATORY

Dr. Wesley Unruh uses the portable Doppler radar he designed to measure wind speeds inside tornadoes.

fifty miles per hour or higher, but it would tip over before any winds got that high," says Davies-Jones. "Besides, it's such a long shot. Tornadoes are rare in the first place. To get TOTO in the direct path of one has proved practically impossible."

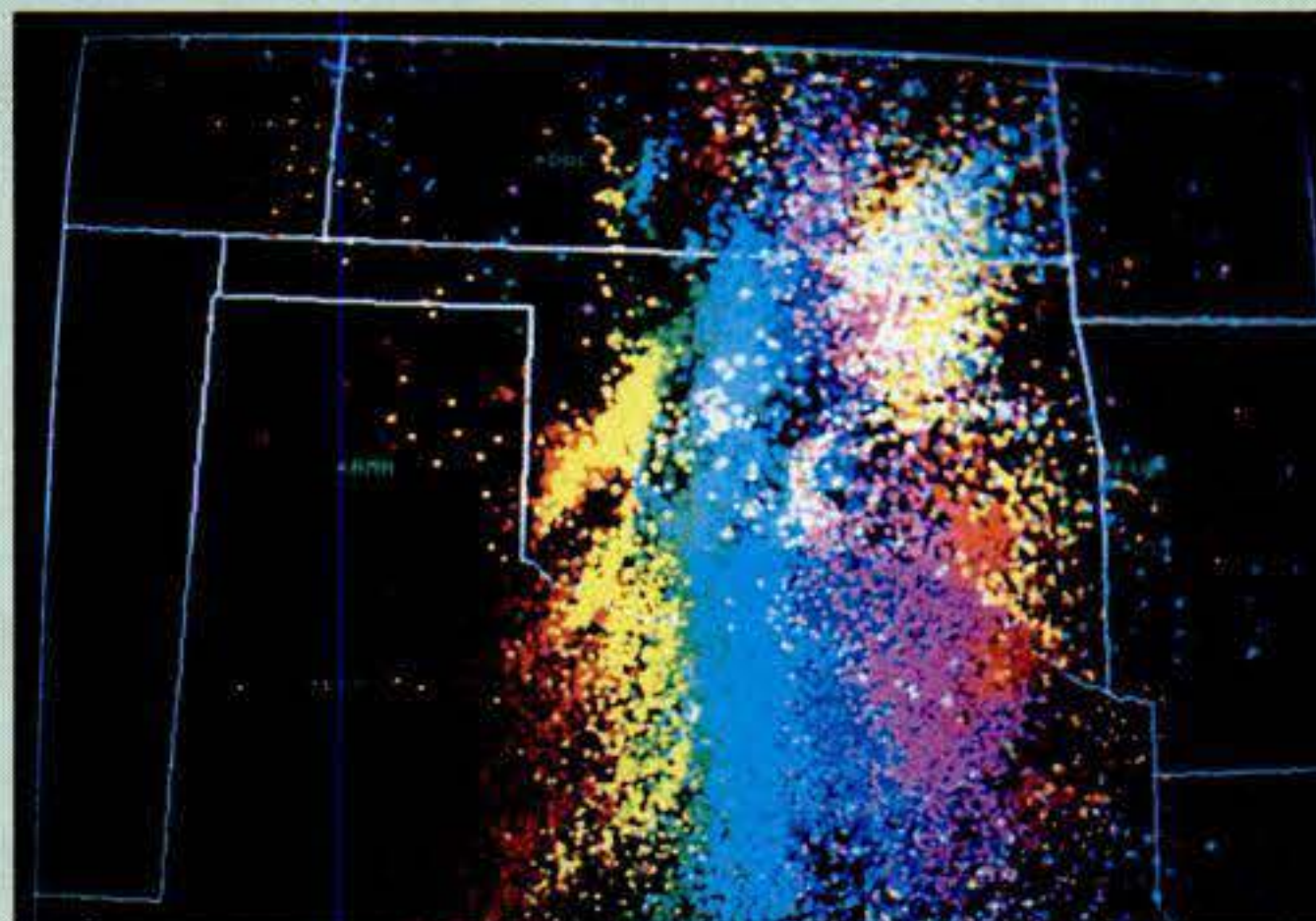
In the early 1980s, chase teams typically drove to areas of tornado activity in beat-up station wagons, using handheld video cameras to document sightings. Today five-person intercept teams from the University of Oklahoma and the NSSL pursue twisters in 15-passenger vans equipped with \$100,000 worth of computer-controlled electronic sensors. Mounted on top of the mobile laboratories are video cameras operated by remote controls inside the van.

Stalking unpredictable prey

The roving research teams don't really chase tornadoes; they try to intercept one without getting trapped in its immediate path. The teams attempt to remain in constant communication with their bases in Norman by radio repeaters, mobile phones, or even roadside pay phones.

I asked experienced tornado chaser Brian Curran what

Chasing lightning



During a lightning display in Oklahoma a few years ago, researchers recorded nearly 24,000 color-coded cloud-to-ground flashes within a 12-hr. period.

NSSL lightning expert Dr. W. David Rust believes lightning found in tornado-producing mesocyclones may differ from that found in ordinary thunderstorms. There are two basic kinds of lightning. Cloud-to-ground (CG) lightning strikes the earth. Intracloud lightning flashes inside or between clouds, or discharges in the air. Cloud physicists suspect the latter type plays a key role during a tornado's formation.

Rust chases lightning using the NSSL's mobile laboratory. "It contains instruments that record data concerning a storm's electric field," says Rust. Rust and colleague Dr. Donald MacGorman have learned that, in the tornadoes they've been able to study, intracloud lightning seems most intense when the mesocyclone is at its peak. But only one type of CG lightning seems to signal a tornado's presence: the positive ground flash. Rarer than other CG lightning, it carries positive charge to the ground, not negative charge as most CG bolts do. In general, the negative CG lightning tends to increase when a tornado begins dissipating. "This might help us predict the demise of a storm's parent circulation," Rust says.

Though lightning research (including maps like the one above) may soon become a legitimate forecasting tool, the study of storm electricity has lagged behind other areas. "We're starting to close the gaps," says Rust, "but we need better sensors of intracloud lightning. Perhaps as early as 1995 NASA is expected to launch a satellite-based lightning mapper. It would allow detailed measurements of both CG and intracloud lightning.—G. D.

a chase is like, and he agreed to show me. That night we left the NSSL after checking the Doppler radar. A line of severe thunderstorms was moving through central Oklahoma, and we headed for three large thunderstorm cells. High winds and large hail were guaranteed.

As the lightning flashed, I scanned the sky for wall clouds. "It's just a strong thunderstorm. Let's pop this one's core," Curran suggested. A moment later we were inside. Conditions: light rain; winds at 30 mph, getting stronger; vicious thunderclaps.

Heavy rain began to pound the car, and we slowed down. "I can hardly see," Curran told me. The windshield wipers couldn't keep pace with the torrents of water. Curran logged in our position: "We're westbound on highway forty, about one and a half miles north of the Cimarron Doppler site," he shouted, as I watched a nearby transformer blow in a shower of sparks. Lightning flashed to the ground about a mile away. Pea-size hail clattered on the car's roof.

We passed a stranded car, and we were out of the storm,

[Continued on page 108]

Kit houses—

600 hours —new tech

Chris and David Ademmer's house in Minnesota is shingled, sided, and trimmed, with windows and doors installed, after 600 hrs. (and 15-min.) of work. David and his father were the prime movers, with Chris's father not far behind. David's uncle helped, as did several friends. Chris handled the painting, decorating—and moral support.



What's it like to build a house from a kit? **POPULAR SCIENCE** set out to answer that question by following two couples as they built identical houses. But the kits supplied were different. One contained all the materials—framing lumber, flooring, sheathing, siding, and roofing—but nothing was precut or preassembled. The other included floor and roof trusses, panelized wall framing, and other preassemblies. The ques-

By **V. ELAINE GILMORE**
Photos by Billy Robin McFarlin

Last June, when David Ademmer carried his bride, Chris Hadac Ademmer, across the threshold, they entered their own sparkling new house. No starter home this: It's a 2,392-square-foot split entry with four bedrooms, two baths, and a 528-square-foot garage.

As the dream of homeownership eludes ever more Americans, how did this young couple (he's 26, she's 21) manage to bring it off?

With a great deal of labor—their own and that of a few relatives and friends. They built the house them-

selves, starting with a panelized kit from a Miles Homes catalog.

Shortly before the Ademmers decided to build, **POPULAR SCIENCE** and Miles agreed to an owner-builder field test (see companion story for details). That required two couples with similar skills building identical houses. The Ademmers became our component builders when they chose a Miles design called the Foxwood. Their building site was near the southern Minnesota town of New Prague. Population: 2,952.

Outside of town, gently rolling pastures alternate with plowed fields. Fences separate one from another like

Continued

new tech vs. old



594 hours —old tech

Dorothy and Marty Rafter stand before their Pennsylvania home after investing 594 hrs. in its construction. There's a roof over their head (albeit unshingled), but no windows or doors are installed and no siding or trim has been applied. It was to take them an additional 340 hrs. to bring their home to the state of completion seen on the facing page.

tion: How much time would the factory-formed parts save the owner-builders? Our "contest" ended when the component house was finished outside—after 600 hours of work. After a similar number of hours the stick-built house wasn't even closed to the weather. Both couples kept daily diaries, not only of hours spent, but of the joys and woes of tackling the ultimate do-it-yourself project. Which way would you choose?

By AL LEES

Photos by Greg Sharko

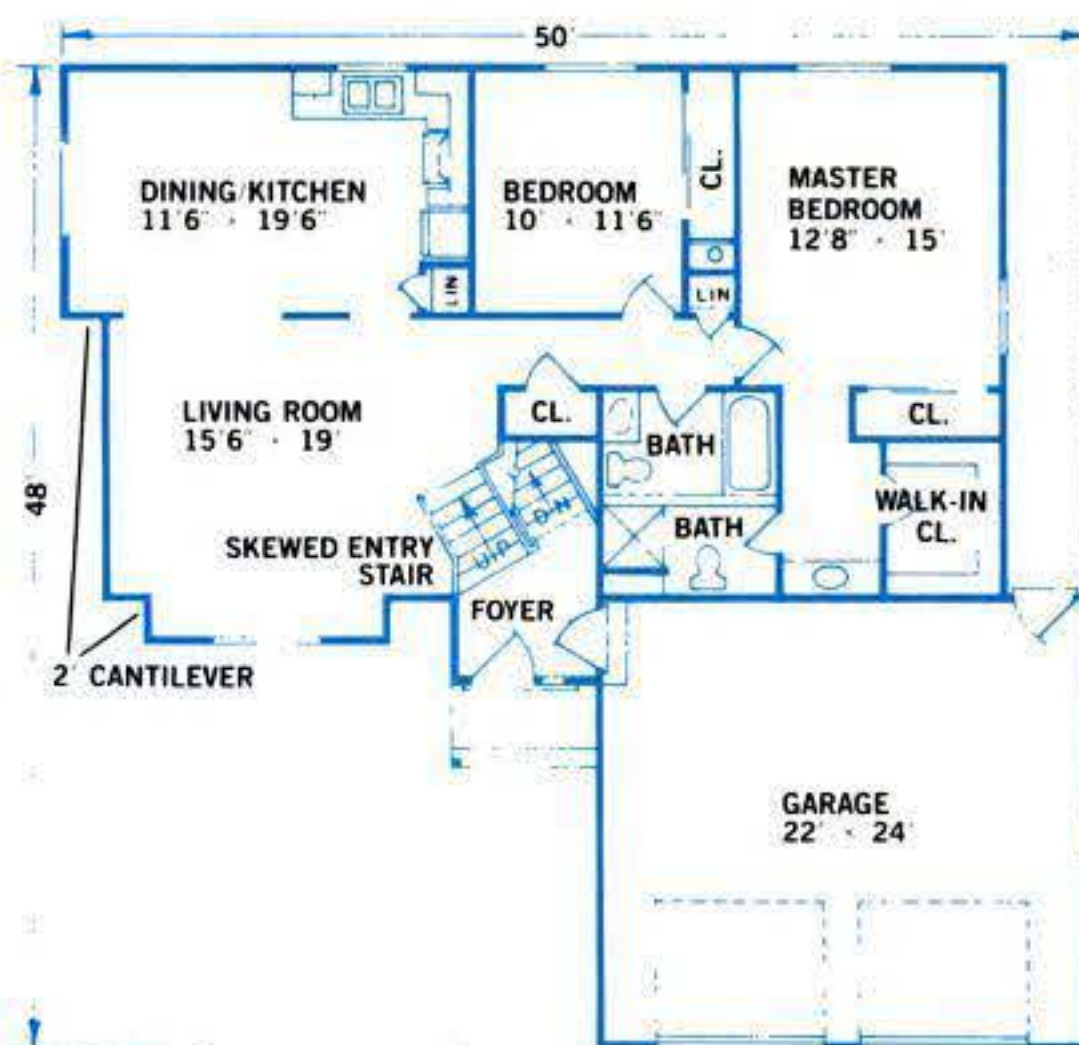
My first visit to the Pennsylvania site was on a raw November day just after Marty Rafter had bulldozed a driveway up his hill to plunk a mobile home on a ledge for his family to live in during construction of its new home. The family—wife, Dorothy, and three small children—seemed surprisingly chipper at the prospect of roughing it through a mountain winter while their house was built farther up the wooded hill.

The Rafters had put their house in suburban Philadelphia on the market and would invest the profit realized

from its sale in a Miles Homes kit; base price: under \$45,000 (including plumbing, heating, and bathroom fixtures). Dorothy and Marty had worked several years on renovations at their old home, so they weren't intimidated that they'd never built a house from scratch.

Dorothy had begun investigating kit packagers when she spotted a newspaper ad for a local Miles Homes seminar. She and Marty attended and liked what they heard about how the company operated. But it was their choice of the Miles' Foxwood model that brought them to the attention of POPULAR SCIENCE.

Continued



Floor plan was identical for both homes, but the Rafters opted to flop it, putting the garage on the left. Angled entry stairs of the split-level house lead up to the main level (shown) and down to semi-excavated living level below. Both owner-builders found framing around stairs tricky and slow. Walls are 2 x 4 studs with fiberglass insulation. Foam sheathing on the outside boosts the insulation value to R-20. Ceiling has two layers of fiberglass batts for an R-40 rating.

An accessible home site in Minnesota allowed Miles to drive its flatbed delivery truck right to foundation. After David Ademmer (center) and helpers unloaded small bundles, the special truck bed's powered rollers eased the bundled components off the truck and onto ground. Items needed first were on top.



Kit house—new tech

Continued

stitches edging the patches of an over-size quilt. Asphalt roads, usually as straight and purposeful as the people, for no apparent reason will occasionally curve or twist.

David Ademmer is a strapping young man with a bit of little boy still in his face and a mop of curly blond hair topping off his mid-height frame. He works as a welder at Minnesota Valley Engineering, seven miles away. David is a man of few words, at least with strangers. And neither he nor Chris, who works in the sales department of the same company, has been bitten by wanderlust. They intend to spend their lives in New Prague.

One good reason to start with a house of their own. "At first we figured we'd rent for a year, but we heard about Miles and the build-it-yourself homes, so we went there one Saturday to a seminar," Chris says in her shy but matter-of-fact way. "My uncle built a Miles kit twenty years ago," David volunteers. "He had good luck with it." Miles soon had a deal.

That was August 1987. Chris and David had already set June 11, 1988, as their wedding date. To start married life in the new house, they'd have to build through a Minnesota winter. David's father, Jerry Ademmer (a foundation contractor), volunteered to help. Chris's father, George Hadac (a retired butcher), also signed on. Neither they nor David had had much carpentry experience, but all were generally knowledgeable about tools.

A Miles house can be customized to a considerable extent. The Ademmers added an exterior door, a deck to the kitchen, and another door on the back of the lower level. Miles does the customizing on CAD terminals in its Minneapolis headquarters, and computer-generated cutting diagrams go off to one of its three plants.

The Ademmers' house was cut and the components assembled at a Miles

Floor trusses span the 27-ft. width of the Ademmers' house. Not normal kit components, Miles supplied them to test the pros and cons. The pros: They saved time and left the lower level unobstructed by support posts. Some cons: They arrived off-square and had to be shimmed. And Miles questions cost effectiveness.



Factory-assembled wall-framing panels used in Minnesota house were light enough for two-person handling—the longest was 12 ft. "We just lifted them up, tacked them down, then leveled and squared everything," says Ademmer. "It went fast—faster than I thought it would."



plant in nearby Owatonna. On my visit I didn't find an automated factory. Components are cut on radial-arm saws. Framing panels are assembled by hand on big tables with metal edges for squaring and red-painted stripes indicating stud placement. Workers use pneumatic nailers to put the pieces together.

All pieces and assemblies are numbered or lettered to match identical codes on the blueprints. "And they're in sequence," manager Vince Bakken points out, "so that as the builders put the house together they don't end up

[Continued on page 100]

David Ademmer and helpers put up roof trusses in 61 hrs., even though location codes were not on the blueprints at the site. (That caused some mislocation that necessitated fixes.) Compare that time with the 199 hrs. the rafters spent cutting and installing rafters.

In paired photos, four on left are of new-tech house, four on right, old tech.

Delivery of kit isn't made until the foundation is in. Mountainous Pennsylvania site kept truck at some distance. Organized stacking is vital and simplifies checking against load list to make sure no pieces are missing or damaged.

Kit house—old tech

Continued

Several months earlier I had visited Miles headquarters outside Minneapolis to discuss a major article based on field research Miles hoped to do. My discussions with Miles executives solidified our plans. We needed two couples who had comparable skills, both tackling their first home-building project, and both choosing the same model. But we needed one couple to opt for all the preassembly Miles could offer, while the other must be willing to invest more "sweat equity" by taking a discounted package with *nothing*

precut—even though it wasn't a standard Miles package.

Fortunately, the Miles operation is efficiently computerized so that the company was able to canvass its national sales to match up two couples for this "contest." POPULAR SCIENCE had selected the Foxwood as an attractive, challenging project for publication. By choosing to buy this model in a nothing-precut kit, Dorothy and Marty Rafter had qualified for the "Great House Race."

What Miles hoped to learn was which "new tech" assemblies—some common to most Miles kits, some under consideration—benefitted the novice builder most. POPULAR SCIENCE wanted to know just how much time factory assembly of some components could save.

Actually nobody told the couples they were in a contest. We didn't want to skew the results by instilling a determination to surpass the other couple. In our frequent monitoring of both projects, Miles and POPULAR SCIENCE revealed only that we had parallel projects afoot in an effort to compare construction experiences. Both couples were provided with identical daily log sheets in which they agreed to enter, after each work day, the number of hours all adults had spent working on the house. Both couples were asked to follow the same logical work sequence, through the 15 construction phases that would bring their houses to a weathertight state, with exteriors completed. (We asked for no record keeping on the subsequent interior work because such jobs as insulating would be identical for both projects, and decisions about finishing and trimming interior surfaces would introduce incomparable variables.)

By chance, the building sites couldn't have been more different: One was in the middle of 40 acres of flat Minnesota cornfield; the one I monitored was on a rocky knoll in a Pennsylvania forest. Further, the Rafters, after

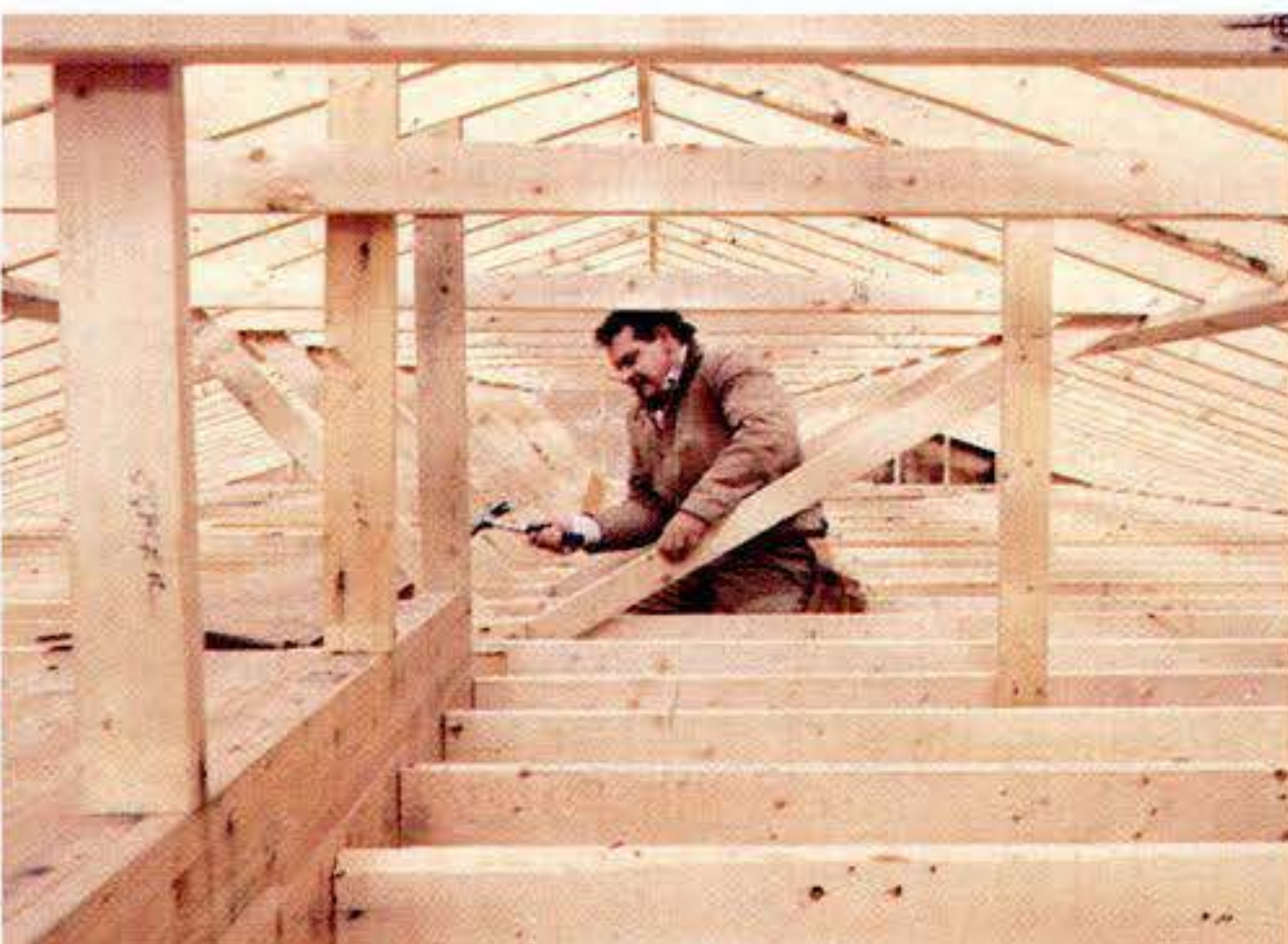
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Because all joists had to be hand cut on old-tech home, framing around the skewed entry stair only added tricky angles to the chore. But without long-span trusses, a central support beam was required for these second-story joists.



Once floor deck was added, every sill and stud had to be cut by hand. Here, Marty is framed by the stairwell. Only after all walls were sheathed could roof framing begin.



Owner-builder Marty Rafter is seen here in a forest of hand-cut rafter assemblies. By far the most time-consuming part of his construction, rafters have no place in Rafter's future, rest assured.

Kit house—old tech

Continued

receiving their blueprint, decided that flopping the floor plan to put the garage on the left made more sense for their site. ("Made all the difference," Dorothy tells me. "The garage now hides a neighbor's barn from our living room. And that's one of the great things about a sophisticated company like Miles: It's flexible about changes—the computer made the switch with all dimensions and labels reversed.")

By my November visit to the Rafter, Marty had already staked out the position of the house on the hip of a hill that falls away sharply in two directions. He'd made a first lame attempt at excavating for the lower floor, and was hoping to get his foundation in before the freeze set in (his property isn't far from Valley Forge, where George Washington and his troops spent a memorable winter).

Because of last-minute snarls in the sale of their old home, the Rafter couldn't schedule delivery before February 6th. (Miles won't deliver until the purchaser documents—with a snapshot—that his foundation is in. In all sales, Miles handles the construction financing, so the company is highly motivated toward getting each house built. It doesn't want to inherit an abandoned project.)

A memorable start

When I visit again in mid-May, I find that the Rafter remember that February day all too well. Marty tells me he "called in all his debts," and was surprised at the number of friends who showed up to help unload. But he wasn't able to keep the day organized, and later regretted he had involved so many inexperienced hands.

"It was a bitterly cold day," Marty recalls, "and care wasn't taken to stack parts in the order they'd be needed later. Not all our counts against the load list were accurate, either."

"Did that mean you had to buy additional materials?" I ask.

"No. When I notified Miles what was short and that a piece or two had come damaged, they delivered replacement material right away. And they supplied *everything*—down to the nails and bolts. I don't think I spent one hundred dollars at the local home center during construction."

Were the blueprints clear and accurate? "A few details were omitted, or confused me," Marty admits. "But Miles supplies phone numbers for its specialists in construction, financing, heating, electricity. There's always help available."

How about on-site help? "It was mainly us," Marty says, tossing an arm around Dorothy. "My dad and

[Continued on page 100]

BOX SCORE

Miles and Popular Science broke the construction into 15 phases. Here's what the two kits contained for each phase—and how many hours each step took the owner-builders.

	Rafters (hrs.)	Ademmers (hrs.)
1 LOWER WALL FRAMING—The Rafters got uncut 2×4s; the Ademmers got assembled framing panels.	42½	23½
2 LOWER BEARING STRUCTURE—The Rafters' house (with floor joists, see below) required a beam and supporting posts in the center of the lower level. The Ademmers' house (using floor trusses) did not require a center support. Both owner-builders had to erect identical bearing-wall framing around the angled stairway.	49	22
3 FLOOR SUPPORTS—The Rafters were supplied with joists, which they cut and installed 16 in. on center. The Ademmers got factory-assembled floor joists to install 24 in. on center.	61	20½
4 FLOOR SHEATHING—The Rafter kit contained standard ply subflooring, which would be topped with ½-in. underlayment. The Ademmer kit contained ¾-in., single-layer, tongue-and-groove flooring, designed to be used with trusses. It is glued as well as nailed.	39*	31
5 UPPER WALL FRAMING—The Rafters got uncut 2×4s; the Ademmers got preassembled framing panels.	63	42
6 WALL SHEATHING—An "apples to apples" comparison that proved to be anything but equal in the doing (see Scoring the Builders, below).	14	56
7 GARAGE WALL FRAMING—Uncut 2×4s to the Rafters; assembled framing panels to the Ademmers.	32½	24½
8 ROOF FRAMING—The Rafters used rafters; the Ademmers used roof trusses.	199	61
9 GABLE-END OVERHANGS—The Ademmers received preassembled overhangs with the soffit boards already applied. The Rafters received material only.	39	12½
10 ROOF SHEATHING	23½*	68¾
11 OVERHANG CONSTRUCTION	32½*	58
12 ROOFING (metal edging, felt, roof vents, shingles)	—	68
13 WINDOWS AND EXTERIOR DOOR	—	13½
14 GARAGE DOORS	—	10
15 TRIM AND SIDING	—	88
TOTAL	594	600¼

*Incomplete at "contest" end. Rafters spent 17 more hrs. on roof sheathing—which put them 28 hrs. faster than Ademmers on this identical task. The prime reason: Ademmers tackled the job in the midst of a Minnesota winter. Rafters also spent 32 more hrs. on overhang construction. And as we go to press Marty Rafter has not laid the underlayment over the subfloor.

Scoring the builders

Miles marketing manager and corporate architect Scott Gerber monitored both sites and analyzed the daily logs of the participants to determine whether our two families were, indeed, equal in skill and efficiency (one of the reasons to include identical steps in our test).

His conclusion: "The Ademmers and Rafter were equal in skill, but they were not necessarily equal in efficiency." He gives the nod to the Rafters. They lost the race only because of the stacked deck.

"Marty Rafter would read the instructions very carefully, get them in his mind, then go ahead," said Gerber. Rafter's superior efficiency showed up most on the wall sheathing. "He rented scaffolding," Gerber explained. "He spent a couple of hours erecting it to form a continuous bridge around the house. Then he put on the sheathing in twelve hours. The Ademmers walked the sheathing up a ladder a piece at a time. It took them fifty-six hours."

But when it came to roofing (step 12) the Ademmer crew proved more efficient: They did the job in 69 hours; the Rafters took 95½. The reason: "Ademmer called in some friends that day who really knew what they were doing," says Gerber.

Efficiency might have been improved with more sophisticated tools. Both groups used only the basics—circular saw, table saw, reciprocating saw, drills, and hand tools. "But the Rafters went for professional tools—twenty-four-ounce framing hammer, worm-drive circular saw," Gerber reported. "The Ademmers tended to use handyman-grade tools." No doubt they would have reduced the man-hours significantly if they had rented (or bought) power nailers and staplers. "But," Gerber cautions, "those can be dangerous, especially the pneumatic nailers capable of driving framing nails. You've got to know what you're doing."

Gerber's advice: Take a systems approach to each task; try to organize it like a production line. And always work with two or three people."—V. E. G.

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PHOTO BY DANIEL D'AGOSTINI

Dirt-cheap dirt floor

A professional rammed-earth home builder shares his methods for pouring low-cost soil-cement floors that are not only durable, but extremely handsome in appearance.

By DAVID EASTON

My family and I live in a beautiful earth home with a handsome earth floor. It may sound unbelievable, but as a successful builder of rammed-earth houses [Nov. '82] I'd been trying for a while to expand the use of earth to finished flooring. After much experimentation, I've finally found a suitable mix of soil and cement to do the job.

Why bother? Well, a soil-based floor is softer and more comfortable than a conventional concrete slab, and if you lay it yourself, it's less expensive. As a bonus, it can be stamped to look like rustic tiling that has an earthy color. Finally, a soil-cement floor is a natural for passive solar heating and a perfect medium for a hydronic radiant slab (see sidebar).

Soil-cement is softer underfoot because it is less dense than concrete. Unlike the aggregate used in concrete, soil expands significantly when it's wet. As a soil-cement slab dries and the soil particles lose water, they shrink, and millions of tiny air pockets develop. These air pockets essentially make the floor a little spongy.

I speak from experience because my family and I have lived in houses with concrete floors and ones with soil-cement floors. Soil-cement is warmer, softer, more forgiving, and just as easy to maintain as concrete. An extra bonus: Dishes rarely break when they hit an earth floor.

Over the years, my firm has tried more than a dozen variations on the

earth-floor theme. We've experimented with a range of moisture contents and methods of application. I now feel confident in passing on the secrets of what my firm calls Terratile—a cast-in-place soil-cement tile.

Starting the subgrade

Terratile can be poured over just about any surface and to any thickness. Our preference is a one-inch-thick Terratile topping poured over a well-compacted four-inch base of rammed earth.

It's best to wait until most construction work is done before putting down Terratile. The tiles need protection from the elements when curing. So we do all of the subgrade work as soon as the foundation is finished and save the rest for later.

To prepare for a slab floor inside a perimeter foundation, you must first install all underground utility lines—plumbing supply and waste lines and electrical and other service conduits. The ground should be flat, fairly level, and firmly packed. Spread two or more inches of sand or pea gravel over the ground as a capillary break, then lay a six-mil polyethylene vapor

barrier over the entire floor area as extra protection against wicking. On top of the barrier spread about three inches of rammed-earth mix; then tamp it down until it's firm and sounds solid. The height of this portion of the subgrade should be about three inches below the desired finished floor level. At this stage we stop working on the floor and proceed with the roof

Continued



A hydronic radiant floor is created (right) by laying down plastic tubing and holding it in place with earth before the soil-cement is poured (see sidebar). In photos far right top and bottom, three stages of soil-cement installation are shown. Mixture has been poured over a compact base (foreground) and is being troweled smooth. Once it begins to firm, it is cut into tiles with concrete stamping tools. After tiles have cured and shrunk apart, they can be grouted (bottom right) and washed.



and the other framing. A little water sprayed on the packed-earth floor every so often will help settle it and keep it from becoming dusty.

When we come back to work on the floor, it's time to lay the piping for a hydronic radiant slab. If that's not part of the plan for the house we're building, we need only bring the level of the base up to within one inch of the desired floor level and tamp it firm. Then we're ready for the topping.

The right mix

Structural concrete is a carefully controlled mixture of sand, gravel, Portland cement, and water. Its strengths and limits are well-documented. Soil-cement, on the other hand, is a not so carefully controlled mixture of soil, Portland cement, and water. The strengths and limits of soil-cement are highly variable, just as soil itself is variable. A coarse, gravelly soil might yield soil-cement that is almost as strong and dense as concrete, while a heavy clay soil will, when mixed with cement and water, yield a material only slightly stronger than a dirt clod.

What we're looking for in a Terratile floor is a balance between the durability of concrete and the low density of soil-cement. There are a couple of other factors, such as workability and setup time, but most importantly, we want the surface to be durable. To be used as a finished floor it has to be able to stand up to a lively game of musical chairs. It takes a sandy soil and at least 12 percent cement to get that kind of toughness.

Some soils are sandy enough to work well for soil-cement just as they are, but most of the soil we come across here in the Sierra foothills is heavy clay—we call it "Calaveras Red." It makes just about the best rammed-earth walls in the state, but it needs the addition of 60 percent sand before it's right for Terratile. On the other hand, in some parts of the San Joaquin Valley, southwest of my home in Wilseyville, Calif., the soil might re-

quire only about 25 or 30 percent sand to make a good mix. No matter what the native soil, though, we almost always add a little bit of sand because it makes the wet mix much more workable.

When using Calaveras Red, we mix three parts sand, two parts soil, and one part cement. In your part of the country the ratio might be different. If your soil is sandy, use only two parts sand. Either way, add one part cement to the other five.

To prepare for mixing a big batch of Terratile, we first have masonry sand delivered and dumped into a pile on our work area. Then we screen (through half-inch hardware cloth) a few yards of native soil into another adjacent pile. We set up our small electric mixer within arm's reach of the two piles (make sure enough sacks of cement are stacked nearby) and get a five-gallon bucket and a charged water hose with a shut-off on the end. The bucket is for measuring the water we add.

Enough water should be added to give the mix the consistency of soft ice cream. Usually that's about one gallon of water per shovelful of cement. A full batch (one wheelbarrow full) in our three-cubic-foot mixer is nine shovels of sand, six shovels of soil, three shovels of cement, and three gallons of water. It takes about seven or eight minutes to mix that quantity thoroughly. A good operator on the mix pile can pump out a yard in about two hours—just the right pace for the person spreading the mix on the floor.

Keeping a level slab

When it's poured thin, as we prefer, Terratile is best worked in small batches. That way you can stamp the tiles as you go, and you don't have to worry about getting too far ahead of yourself. The thin Terratile takes an initial set and is ready for stamping after only 30 minutes because the earth base draws water out of the wet mix long before the cement starts to

hydrate. A good-size crew for pouring Terratile is three people, one to mix and deliver, one to spread, and one to stamp.

It's difficult to keep the floor flat and of uniform thickness when working with only wheelbarrow-sized batches. To maintain level, we use string lines, a four-foot level, a three-foot finishing trowel (called a darby), and a 24-inch steel trowel. Even with these tools and a lot of skill, it's still tricky to keep the floor really flat. In fact one of the characteristics of Terratile is a certain unevenness, which in the end contributes to the handmade look.

Start pouring in the far corner of the room. Spread the mix out using a steel trowel, first working the mix up against the edge of the building where you've marked your pencil or chalk level lines. Spread the mix in a band just over two feet wide, parallel to the far wall. One wheelbarrow full will cover 8 to 10 square feet. By the time you've covered the width of the room, the batch should be ready to stamp. (I'll get to stamping in a minute.) After you've spread the first band, you can no longer work from the clear mark on the foundation. Here's where you'll need the four-foot level. Dump a batch of mix; spread it around and up against the first band you poured; work the old and the new together at the edges to get good intermixing; then level out from the mark on the foundation to make sure you're not climbing or dropping. We use the darby to keep the interfaces flat.

You can use a string line pulled taut across the room to check the level every so often; but if you were careful to get the subgrade flat and level, the thickness of the Terratile itself should be a good indicator of how you're doing. Keep up the pouring and spreading until you've finished the room or until you're ready for a break. When you take a break, do it after you've completed a band. That way, when you come back to work, you can cut back to the last stamp line and the seam

[Continued on page 104]

While you're at it, why not pour a hydronic radiant floor?

Circulating warm water through a soil-cement floor, whether the water is warmed by the sun or by fossil fuels, creates a comfortable environment. The heat is low, where your body wants it, but no noisy blowers and bulky air ducts are required. And now, with readily available flexible polybutylene tubing, the major drawback to radiant slabs—cracked pipes under the slab—has been eliminated.

To start, purchase a 1,000-foot roll of 1/2-inch polybutylene tubing. To keep heat evenly distributed, you'll want several different zones, each using no more than 250 feet

of run. Determine where you want your manifold (a centrally located closet is preferable) so that you can begin and end all runs there. Set up a temporary batter board to tie off the ends of the tubing until after the floor pour. For each room lay out the tubing using 12-inch spacing. Be careful not to run the tubing under any future framed wall. You can even run the tubing to places you want the warming first, for example, along the sides of your bed or next to the shower.

Start at the manifold and roll out the tubing along the path you've mapped. Have your

partner follow behind, piling soil mix on top of the tubing to hold it in place as you roll it out. Don't spare the mix, because you'll be using it before long to raise the floor level in preparation for the Terratile.

Roll out the tubing for each zone in this same manner and then spread the rest of the soil mix—enough to just cover the tubing. The tubing should be close to the slab, but not actually in it. Rake, level, and hand tamp the mix until it's firm. Spray the floor lightly with water to help settle it and to moisten the subgrade before you pour the Terratile.—D. E.

HOT NEWS IN HOME HEATING

Just when you thought it was safe to squander energy again, climatologists have come up with a compelling reason to save. The long-predicted greenhouse effect, the warming of Earth because of pollutants that keep infrared energy from radiating back into space, seems to have arrived. The pollutants come mainly from burning fossil fuels. The implications are ominous: not just warmer weather, but a rise in sea level and changes in weather patterns that could disrupt agriculture. Public policy may have to be altered; individual conservation efforts will take on renewed importance. The products on the following pages could help you take a step in that direction, without compromising comfort or convenience. —V. Elaine Gilmore

Give your house a

Aaahhh. It's the end of the day; you're reclining in your simulated leather Barca-lounger smoking a big stogie, slippers resting on the acrylic pile carpet; your faithful dog lying at your side. In the attached garage, your car cools down after the commute home. And your wife is preparing a garlicky concoction that soon has the room smelling like Anthony's Italian Kitchen. But before you take a swig of beer, think for a moment about what you don't see: indoor air pollution.

Synthetic materials, household chemicals, poorly vented stoves, attached garages, animals, and even excess moisture are all sources of indoor air pollution. Formaldehyde, nitrogen dioxide, particulates, and carbon monoxide are the most common. Radon, a radioactive, cancer-causing gas emanating from the soil beneath a house, is a particularly worrisome culprit.

Tightly built homes save energy, but the reduction in ventilation measured in air changes per hour (ACH) can exacerbate an existing problem. The best solution for indoor air pollution is to remove the source. But if that's too expensive (tearing out formaldehyde-gassing particle board), or impossible (eliminating the cigar smoker), mechanical ventilation could be the answer. And if you live in a colder climate, a ventilator that recovers heat from the house exhaust—a heat re-

covery ventilator, or HRV—would be an even better choice. HRVs have been around for several years ["Heat-Saving Vents," Jan. '83], but new models with higher efficiencies and more features warrant another look.

The principle of an HRV is simple. One fan pulls in cold fresh air while another is blowing out warm stale house air. The actual heat exchanger, the core of the unit, picks up the heat from the exhaust and transfers it to the incoming stream. Optimally, the two streams will not mix. There are several different types of exchanger cores (see drawings): plate type, rotary wheel, and a core made from heat pipes are the most common.

Most HRVs come with removable air filters, and some have optional electronic air cleaners to also keep outdoor pollutants from entering the house. Window or wall-mounted HRVs are available for single rooms or apartments, but the most effective—and expensive—systems require their own ductwork.

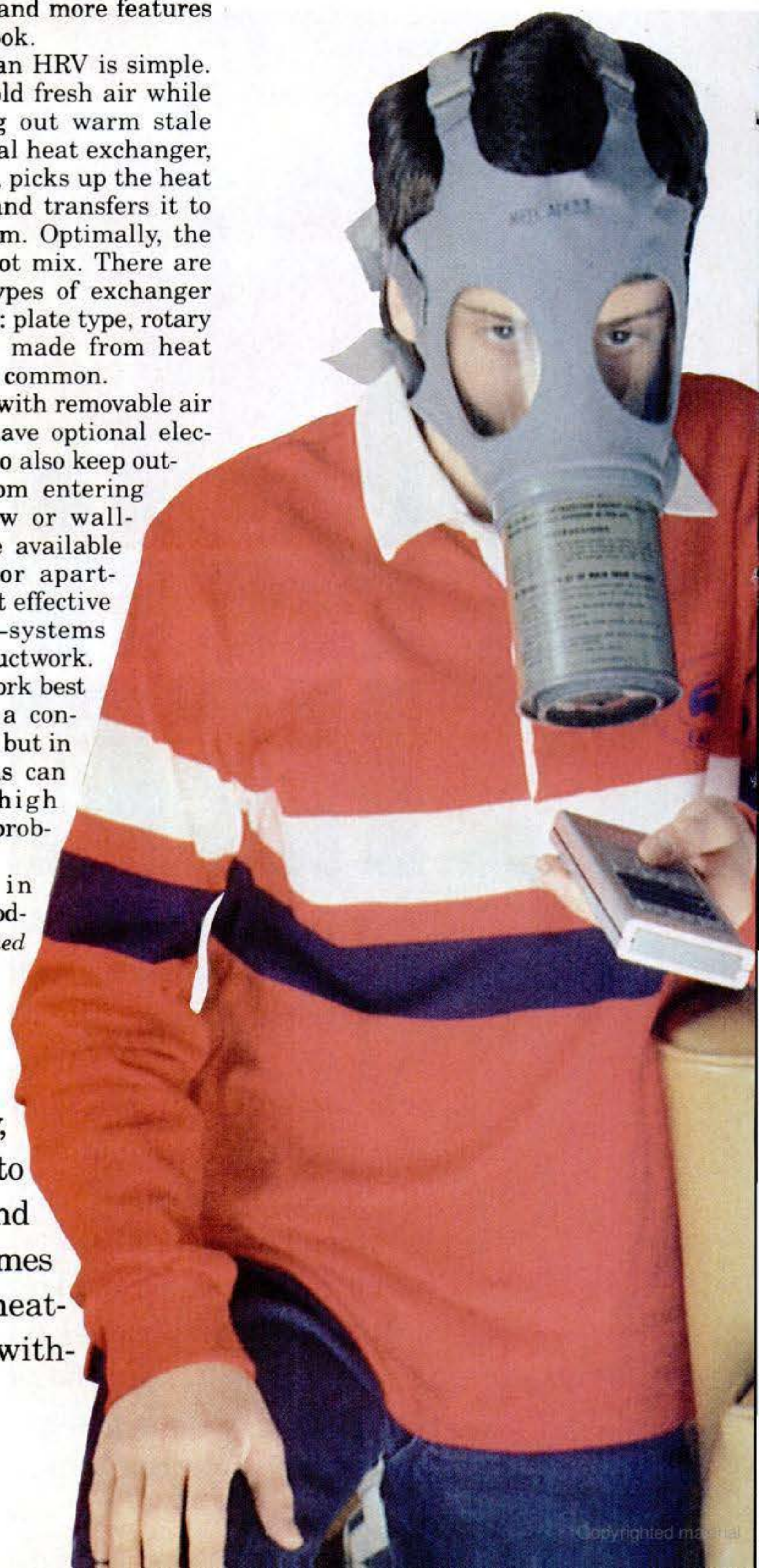
The ventilators work best when they run at a continuous low setting, but in most units the fans can be turned on to high speed to ventilate problem areas.

The big news in HRVs is that the prod-

Continued

Is your house gasping for air? While tightly constructed homes save energy, their low air-change rates can lead to problems with indoor air pollution and excess moisture buildup. Even leaky homes can suffer from radon infiltration. A heat-recovery ventilator can clear the air without sacrificing heat savings.

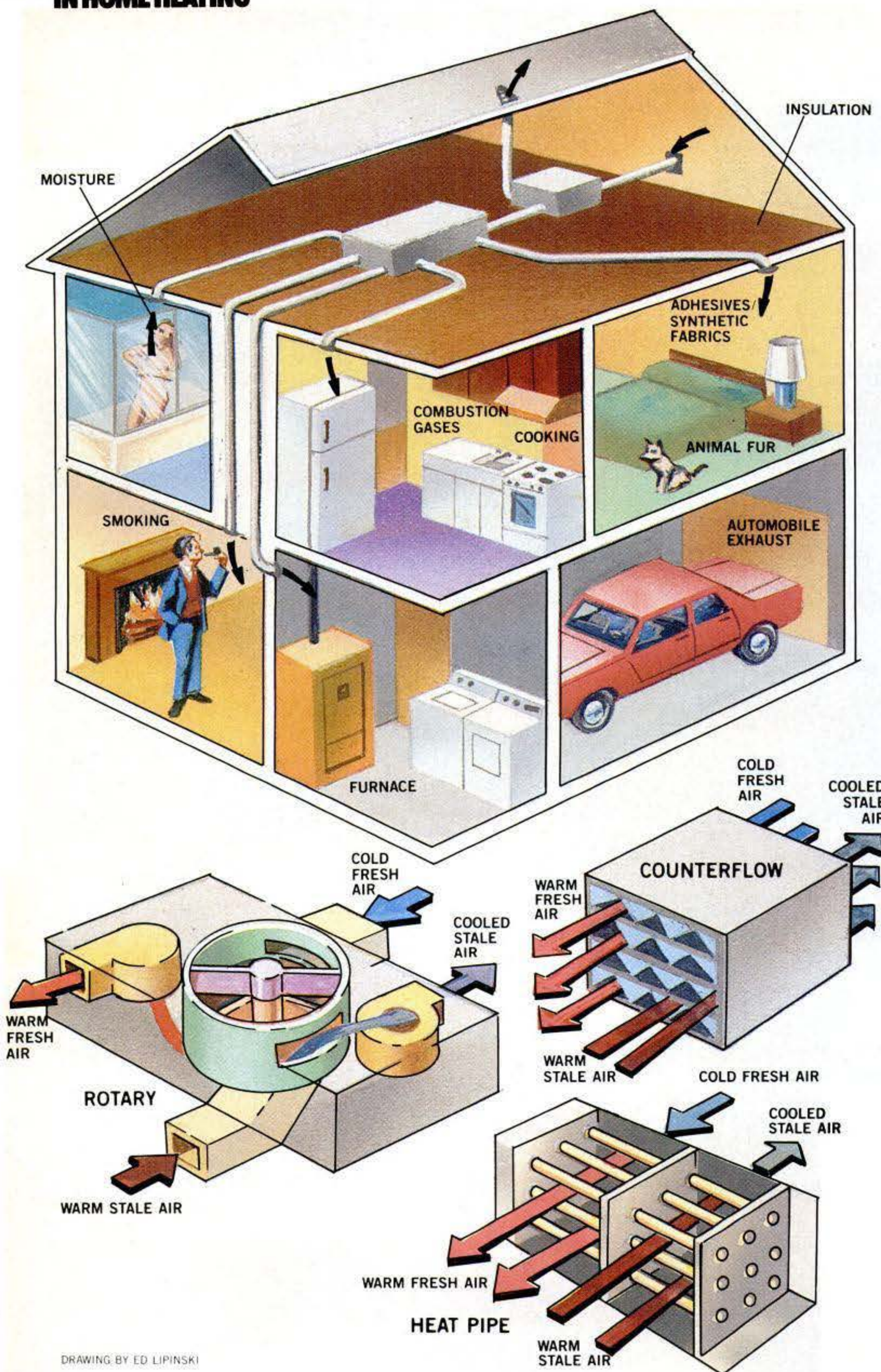
By NAOMI J. FREUNDLICH



breather



PHOTO BY GREG SHARKO



DRAWING BY ED LIPINSKI

ucts are improving. Colin McGugan should know. He is the supervisor for HRV testing at the Ontario Research Foundation in Mississauga, Ontario. The laboratory performs a standard test that certifies Canadian HRVs for use in a government low-energy housing program called R-2000.

"Manufacturers have improved their fans so that they can move more air. They've tightened up the cores so there's less cross leakage. And in some cases they've increased their heat-

recovery efficiency," says McGugan. This recovery efficiency can be loosely defined as the ratio of the heat recovered to the total heat that could be recovered by a "perfect" exchanger.

For example, if the cold incoming stream is 30 degrees F, the exiting stream is 70 degrees, and the air supply from the exchanger is 60 degrees, the exchanger's efficiency is 75 percent of the theoretical maximum (30 degrees of a possible 40 were transferred). The Canadian standard for

The sources of indoor air pollution include building materials, cleaning products, improperly vented combustion appliances, and attached garages. A whole-house heat-recovery ventilator is typically located in a basement or attic. One fan brings stale air from bathrooms and kitchens through ductwork to the exchanger core where, in winter, it gives up heat to incoming fresh air. The warm fresh air is sent through the house as ventilation and the cool stale stream is exhausted. In cooling season the opposite takes place.

Heat exchangers employ several core types. With a flat-plate core, multiple plates separate tiny air channels of supply and exhaust air streams. The streams can either run parallel in opposite directions—counter flow—or perpendicular to each other—cross flow. In a rotary core, a porous plastic wheel revolves slowly from the warm airstream to the cold airstream, picking up heat from one and delivering it to the other. An optional desiccant-coated wheel also transfers moisture from the warm to the cool stream. In a heat-pipe core, as warm air runs past one end of the pipe, the refrigerant vaporizes and moves to the other end of the pipe. As the cold stream passes by this end, the refrigerant condenses and gives up its latent heat. The condensed refrigerant then wicks back and the cycle repeats.



HRV MANUFACTURERS

	Model	Type	Core type	Net airflow ¹ (cfm)	M.L. (%)	Efficiency ² SRE(%) (32°F - 13°F)		Max. power consumption	Sugg. retail (\$U.S.) ³
Air Changer Marketing 1297 Industrial Rd. Cambridge, Ontario N3H 4T8	DRA150 DRA275	ducted ducted	counter flow counter flow	104 231	76 78	76 78	57 56	84 W 260 W	595 945
AirXchange, Inc. 401 V.F.W. Dr. Rockland MA 02370	502 570D 570	ducted ducted wall mounted	rotary rotary rotary	142 65 70	75-80 75-80 75-80	77 n.a. ⁴ n.a.	43 n.a. n.a.	145 W 45-55 W 45-55 W	495 376 360
Altech Energy 7009 Raywood Rd. Madison WI 53713	NewAire HE-1800C NewAire HE-2500 NewAire HE-5000	ceiling mounted ducted ducted	cross flow cross flow cross flow	70 110 210	73 78 78	n.a. n.a. n.a.	n.a. n.a. n.a.	55 W 120 W 240 W	400 535 795
American Alides Ventilation Corp. 4539 Northgate Ct. Sarasota FL 34234-4864	VMP-H 3/5 VMP-H 4/8 VMP21 6/7	ducted ducted ducted	counter flow counter flow counter flow	90/140 130/180 150	70 70 70	n.a. n.a. n.a.	n.a. n.a. n.a.	145 W 170 W 140 W	980 ⁵ 995 ⁵ 1,496 ⁵
BossAire 1321 Tyler St. N.E. Minneapolis MN 55413	BX-125 BX-150 BX-250 BX-350	ducted ducted ducted ducted	cross flow cross flow cross flow cross flow	125 184@0.4 279@0.5 377@0.5	80 80 80 80	n.a. n.a. n.a. n.a.	n.a. n.a. n.a. n.a.	160 W 220 W 250 W 314 W	772 880 1,211 1,498
Conservation Energy Systems 3310 Millar Ave. Saskatoon Saskatchewan S7S7G9	VanEE 1000 VanEE 2000 VanEE 2000+	ducted ducted ducted	cross flow cross flow double cross flow	129 216 237	n.a. n.a. n.a.	55 70 83	49 60 57	1.2 amps 2.05 amps 2.05 amps	450 550 1,150
Des Champs Laboratories Box 440 17 Farnella Dr. East Hanover NJ 07963	E-Z-Vent 210 EZV-220 EZV-240 EZV-310 EZV-320 EZV-340	ducted ducted ducted ducted ducted ducted	counter flow counter flow counter flow counter flow counter flow counter flow	115/150 180/240 325/430 110/145 165/220 310/415	75 73 72 85 84 83	n.a. n.a. n.a. n.a. 67 n.a.	n.a. n.a. n.a. n.a. 70 n.a.	0.8 amps 1.5 amps 3.0 amps 0.8 amps 1.5 amps 3.0 amps	700 760 920 770 840 1,010
Enermatrix, Inc. Box 466 Fargo ND 58107	EMX-10 EMX-15 EMX-20 EMX-25	ducted ducted ducted ducted	unbalanced cross flow cross flow cross flow cross flow	96 90 113 250	50 n.a. n.a. 71-84	n.a. n.a. n.a. n.a.	n.a. n.a. n.a. n.a.	2.0 amps 1.5 amps 2.8 amps 2.42 amps	399 429 479 899
Environment Air Ltd. Box 459 Bouctouche New Brunswick E0A0G0	ENV-W60 ENV-K5 ENV-K6 ENV-K8 ENV-K10	wall or window mounted ducted ducted ducted ducted	heat pipe heat pipe heat pipe heat pipe heat pipe	60 125 190 290 590	65-80 60-80 60-80 60-80 60-80	n.a. n.a. 63 63 n.a.	n.a. n.a. n.a. n.a. n.a.	40 W 180 W 180 W 240 W 388 W	460 630 795 1,100 1,480
Les Industries Douvent Ltée. 1375 Boul. Charest Ouest (Suite 6) Quebec PQ G1N 2E7	Fan-X-Changer WR-2S	ducted	capillary wheel	210	50	n.a.	n.a.	1.2 amps	480
Nutech Energy Systems 124 Newbold Ct. London Ontario N6E 1Z7	Lifebreath 100DEF Lifebreath 200STD Lifebreath 200MAX Lifebreath 300 DCS Lifebreath 195 DCS	ducted ducted ducted ducted ducted	cross flow cross flow cross flow double cross flow double cross flow	64 182 193 220 182	80 n.a. n.a. n.a. n.a.	64 80 70 79 80	58 77 69 75 77	136 amps 100 W 114 W 234 W 161 W	850 995 800 1,295 1,195
QDT, Ltd. 1000 Singleton Blvd. Dallas TX 75212-5214	SAE-150	ducted	heat pipe	150	70	n.a.	n.a.	125 W	599
Raydot Inc. 145 Jackson Ave. Cokato MN 55321	Raydot	ducted	counter flow	225	73-82	n.a.	n.a.	135 W	890
The Star Heat Exchanger Corp. Nova B109-1772 Broadway St. Port Coquitlam British Columbia V3C 2M8	165 200 300	wall or window mounted ducted ducted ducted	counter flow counter flow interface tube counter flow Interface flow counter flow	70 160 180 240	60 80 80 80	n.a. n.a. 79 79	n.a. n.a. 67 67	34 W 66 W 66 W 132 W	307 570 652 826
Vent-Aire Engineering Development, Inc. 4850 Northpark Dr. Colorado Springs CO 80907	ECS 10 ECS 20	ducted ducted	counter flow counter flow	100 220	65 75	n.a. n.a.	n.a. n.a.	58 W 168 W	354 884
XchangeAir Corp. Box 1565 Fargo ND 58103	BDR-95 BDR-210 BDR-315	ducted ducted ducted	cross flow cross flow cross flow	80 135 255	80 80 80	n.a. n.a. n.a.	n.a. n.a. n.a.	122 W 250 W 250 W	540 740 975

Notes: ¹Net airflow is given at 0.3 in. (a standard measure of static pressure), except where indicated. Dual listings are for lo/hi airflows; ²manufacturer's listed (M.L.) efficiency is not confirmed by independent tests. Sensible recovery efficiency (SRE) is an independent result from tests performed at the Ontario Research Foundation at a net airflow of 117 cfm; ³suggested retail price usually includes core, housing, two fans, filters, and basic controls. Ductwork and insulation are extra; ⁴not available; ⁵price includes most accessories

heat-recovery efficiency is more complicated, taking into account electrical energy consumed by fans and defrost. Called the "sensible recovery efficiency" (see table), this will decrease in colder climates. Increasing the surface area for heat exchange by using a double core is one way to improve efficiency.

Another important improvement in today's HRVs is defrost capability—especially important for areas where temperatures frequently drop below zero. In cold weather the heat-transfer

surface can dip below the dew point of the exhaust stream, causing moisture to condense out. When the moisture freezes, ice can block the exhaust vent, vastly lowering the HRV's efficiency.

According to William J. Fisk, a staff scientist at Lawrence Berkeley Laboratory who led early research on ventilation and indoor air quality control, five years ago most units either had no defrost mechanism or used an energy-hungry electric preheat to warm incoming air upstream from the exchange-

er. Now many units employ defrost mechanisms that automatically shut off cold supply air for several minutes and recirculate warm house air through the core.

Heat-recovery ventilators are not for every home—sometimes a more direct approach to pollution reduction is cheaper and more effective. Properly venting heating and cooking appliances as well as an attached garage could reduce high levels of carbon monoxide, nitrogen dioxide, and particulates. Getting rid of household chemicals (cleaning fluids, paint thinners, and pesticides) could reduce organic chemical concentrations. Booklets on identifying and reducing household pollutants are available from the American Lung Association.

An HRV is most effective in a "tight" house: one that receives minimal infiltration, 0.5 ACH. In a leakier home airflow is diverted from the heat exchanger and defeats the energy-recovery process. If you live in a temperate climate, opening some windows might also be enough ventilation. But Fisk says, "When you have a combination of a severely cold climate and relatively high energy prices, an HRV looks attractive." He adds, "Some leaky homes with specific pollution problems—a moderately elevated concentration of radon or formaldehyde—would also benefit from an HRV."

Pasqual Franco had such a problem. He found an elevated radon concentration in his basement. Franco's 20-year-old Connecticut home is weatherized, but was built before the era of tight homes. He installed an HRV to continually flush the air out of his 45-by-45-foot basement, and with it went the dangerous radon reading. "I had radon readings of over four picocuries [per liter of air, the level at which the EPA recommends remedial action]," says Franco, "but after I installed this heat exchanger the level dropped to only 1.1." A word of caution: If you've got radon above 15 pci/liter, an HRV is not for you. Fisk's computer modeling has shown that a severe radon problem will not be remedied by dilution with an HRV.

Radon is one reason homeowners install HRVs. But in Canada, at least, excess humidity seems to be the most common problem. In tight houses condensation builds up and can't leave the house via cracks and leaks. Says Craig Henderson, a sales manager for Nutech Energy Systems in London, Ontario: "I've seen homes that actually

Continued

sweat." The moisture can cause mold and mildew growth, and it can rot the structure and soak the insulation. For this reason, as well as general comfort, Canadian Energy Mines and Resources strongly recommends an air-to-air heat exchanger in all R-2000 certified homes.

But to rid a home of excess moisture the HRV must have a "sensible heat" core—one that doesn't transfer moisture (latent heat). Flat-plate cores and heat-pipe cores exhaust the moisture in the stale air. But rotary wheel exchangers can have permeable membranes and recover moisture with the heat. The rotary wheels are advantageous in a cold, dry home as well as for use with an air conditioner.

"In the cooling season a lot of the heat-exchange load is moisture and sensible cores don't remove this," says McGugan. With a rotary exchanger, moisture is removed from incoming air and transferred to the exhaust.

Comparing performance

Choosing the right HRV for your home isn't simple. A heat exchanger's capacity is rated at cubic feet per minute (cfm). So to find the right unit to provide a given ACH, you must know your house's volume in cubic feet.

Virtually all units made in Canada have been independently tested and certified for R-2000 use. The resulting performance figures, including efficiency at a range of air volumes, pressure, and temperature, allow the consumer to make an educated choice. In the United States the Home Ventilating Institute (HVI) has put together a standard—almost identical to the Canadian test—but so far few manufacturers have had their units tested. That leaves the consumer dependent on manufacturers' claims of efficiency.

In practice, heat exchangers seem to perform below expected efficiency. A recent study by Battelle's Pacific Northwest Laboratories in Richland, Wash., of 38 energy-efficient homes found exchangers averaging 52 percent efficiency.

Many reports of poor heat-recovery efficiency and air delivery far below manufacturers' claims are the result of improper installation, according to Nick Des Champs, president of Des Champs Laboratories (makers of E-Z-Vent units) in East Hanover, N.J. "If the ductwork is installed improperly, there can be such a high pressure loss through the ducts that no air flows," he says. The installation problem is also being addressed by the HVI, which in conjunction with the Bonneville Power Authority is implementing an installation training program to help beef up field HRV performance. **PS**

Two routes to radiant floors

On a frosty winter morning the thought of your snugly warm toes traipsing across an ice-cold floor makes you gather your blanket up to your nose. With radiant floor heat you won't have that excuse to stay in bed.

Radiant floor heating systems generally heat your house by hot water running through pipes in a concrete floor slab, heating the slab and thus the house. Infloor Heating Systems, a division of Gyp-Crete Corp., now offers two systems: One uses plastic pipes to carry hot water; the other uses electric heating cables. Both can be laid over existing concrete slabs or wood flooring. Then they're topped with a special gypsum cement. An Infloor floor surface radiates an even, comfortable warmth. "We design our systems to keep floor temperatures below eighty-five degrees [F]," a standard temperature limit for comfort, says John Fantauzzi, technical services manager of Infloor. "Beyond that, and your feet get too warm."

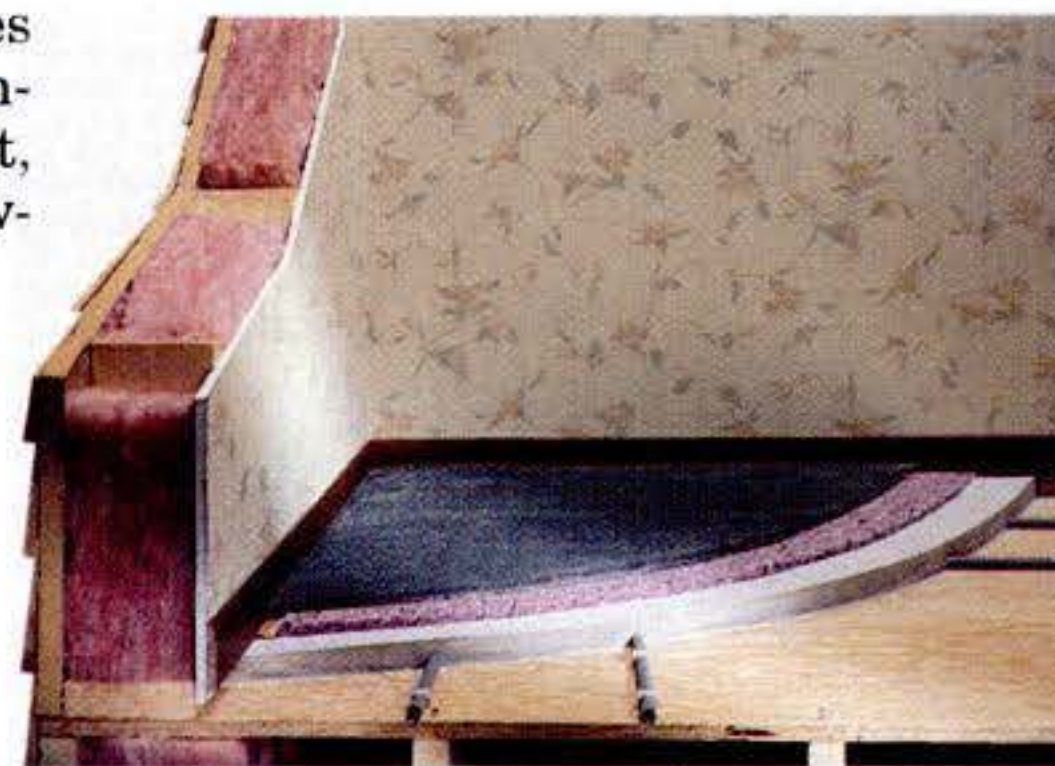
The Infloor hot-water system can tie into any heat source—boilers, heat pumps, solar collectors, water heaters—that can deliver water from 140 to 180 degrees F. At its heart is the Zone Control, a mixing valve and pump that maintain the desired floor temperature.

To install the hydronic system, polybutylene tubes are stapled to the plywood subfloor or laid over insulation board on a concrete slab, and a 1¼ inch layer of lightweight non-structural gypsum cement, called Gyp-Crete 2000, is poured over them. "Portland cement is around 150 pounds per cubic foot," says Phil Turner, new product development director of Gyp-Crete Corp. "Our gypsum cement is approximately 110 to 115 pounds per cubic foot."

For electric-resistance radiant floors, spacer strips establish the floor pattern and maintain a constant distance between the runs of cable. An Infloor



A layer of gypsum cement, called Gyp-Crete 2000, is poured over electric cable laid out on a plywood subfloor to form an electric radiant heating system.



Warm-water pipes embedded in the Gyp-Crete form hydronic radiant floors. Either system can be covered with carpet, tile, wood, or vinyl.

thermostat controls the temperature; a sensor embedded in the gypsum keeps the cable from overheating.

"Homeowners can save money on their heating bills," Fantauzzi concludes, "because the even distribution of heat reduces heat loss." Proponents also point out that radiant heat warms people directly, so you may feel comfortable at lower thermostat settings. But the best benefit of all: no more cold toes! Infloor Heating Systems, 920 Hamel Rd., Box 253, Hamel, Minn. 55340.—Cheryl M. Fiorillo

Last winter an eastern Pennsylvania heating and plumbing contractor, Harold Huggler, replaced his oil-fired boiler with an electric heating system with a 600-gallon tank of water, which he heated only at night at off-peak rates offered by Pennsylvania Power and Light in Allentown.

With electric heat, no combustion takes place in the house, a plus for indoor air quality. And it can be part of the picture in reducing outdoor pollution as well, because electricity can be generated by wind, water, solar, or nuclear energy.

The primary benefit Huggler is enjoying from this prototype system is improved comfort. The reason: smart valves added by Bradford Smith, residential technical specialist at PP&L, which co-sponsored the installation as a test of load-leveling schemes. The valves, from DuroTron in Bridgewater, N.J., were invented by Bob Hughes, chief engineer there, and colleague Ian Sturrock. At \$165, they are claimed to be much cheaper than competing devices.

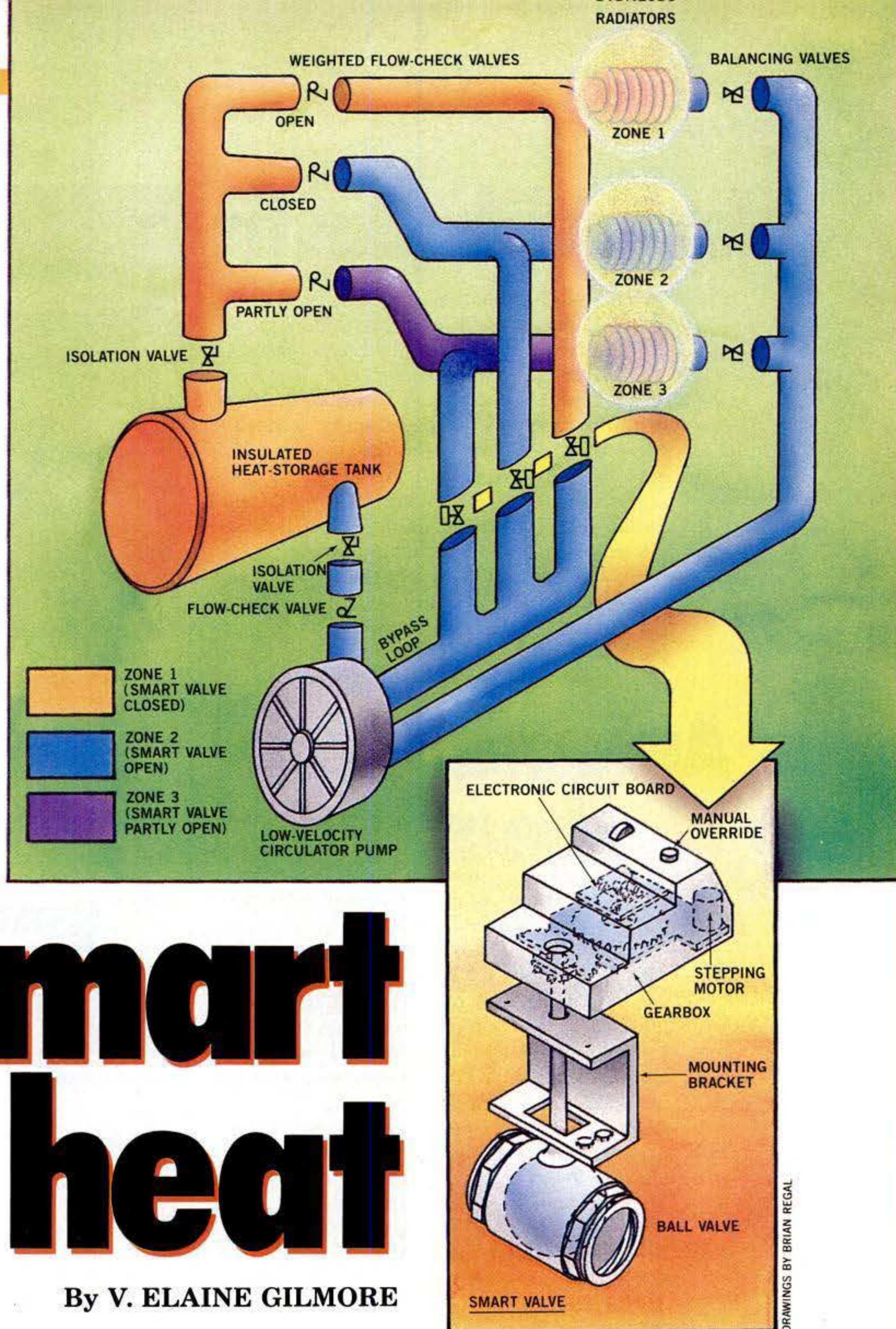
Electronic controls for the valves keep room temperature smack on the thermostat setting. The basic control signal is a voltage that varies with the magnitude of the difference between zone temperature and thermostat setting. "It says, 'Hey, I'm below the set point, open up,'" Hughes explains. "Then pretty soon it says, 'Hey, I'm at the set point, close down.'" But thermal inertia makes room temperature continue to rise or fall. "That can mean a five-degree swing," says Hughes.

To avoid such uncomfortable swings, the DuroTron control considers the *rate of change* in the difference between temperatures. The controller anticipates their convergence and adjusts water temperature. A chart recorder showed that room temperature varied less than one degree F.

Huggler paid \$1,930 for all of his electricity last year, including heat, at the off-peak rate averaging 3.80 cents per kilowatt-hour (versus an average 7.82-cent standard rate). The prior year (degree-day corrected) he spent \$1,958 on electricity and heating oil. So for the same operating cost Huggler has a system with improved comfort and cleanliness.

PP&L has integrated smart-valve technology in a heat pump thermal storage system and hopes to do more field tests this winter.

P 3



Smart heat

By V. ELAINE GILMORE

Water continually circulates through all zones of this hydronic heating system. Smart motorized ball valves determine whether hot water from the storage tank, cold water from a bypass loop, or a combination of the two, flows through a zone.

Zone 1 here is currently requiring the most heat. Its smart valve is closed, which stops water flow in the bypass loop. In that circumstance, pressure upstream of the weighted flow-check valve (upper left) is higher than that downstream of it, so the valve opens, letting hot water pass from the storage tank to the zone 1 radiators, which release heat to the rooms. (Balancing valves adjust water flow to ensure that the heat is removed in the radiators.)

Zone 2 is not currently calling for heat. Its smart valve is open, which opens the bypass loop. This increases the

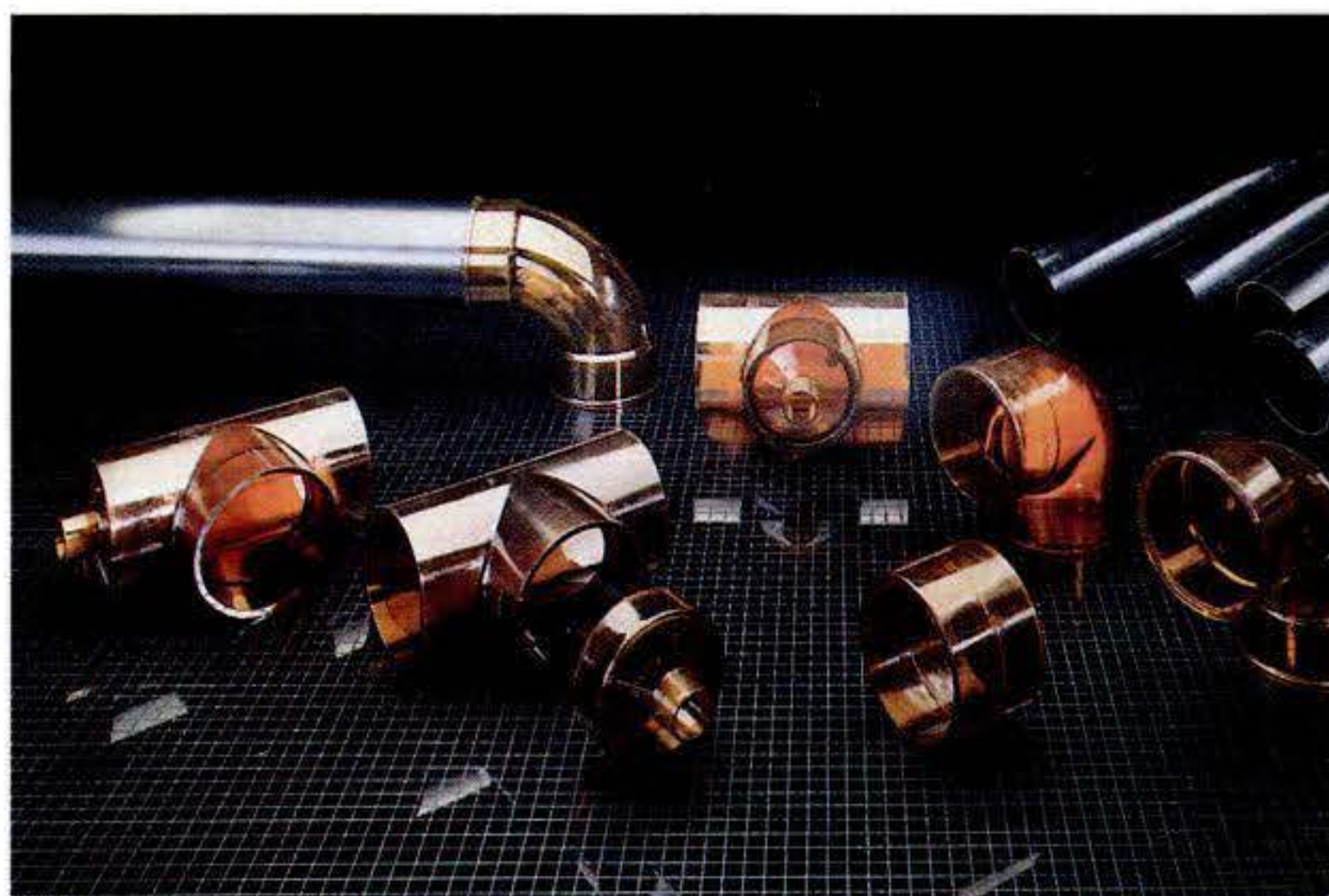
pressure downstream of the weighted flow-check valve. It closes, halting the flow of hot water from the storage tank. Consequently only cold (room-temperature) water is flowing through zone 2.

Zone 3 needs some heat, but not as much as zone 1. Its smart valve is being pulsed (from closed to partly open). That lets some cold water from the bypass loop flow and also varies the pressure in the line so that some hot water from the storage tank flows through. By varying the pulsing rate, the water can be hotter or cooler as the zone's heat needs require.

The electric-resistance heating element cannot come on during peak hours, so enough heat must be stored in the water at night to take care of the following day. An outside temperature sensor regulates that.

Vent with plastic

Flue-pipe corrosion: That is a drawback to today's high-efficiency furnaces and boilers, whose corrosive flue gases are cooler and therefore tend to condense in metal vents. Condensing furnaces—the flue-pipe temperatures of which run below 150 degrees F—solve that by using PVC pipes. Now there's a solution for higher-temperature noncondensing units: vents using G.E. Plastics' Ultem resin, said to withstand temperatures up to 480 degrees. Plexvent (shown) is made by Plexco (3240 N. Mannheim Rd., Franklin Park, Ill. 60131); Ultravent comes from Hart & Cooley (500 E. Eighth St., Holland, Mich. 49423).—*Timothy O. Bakke*



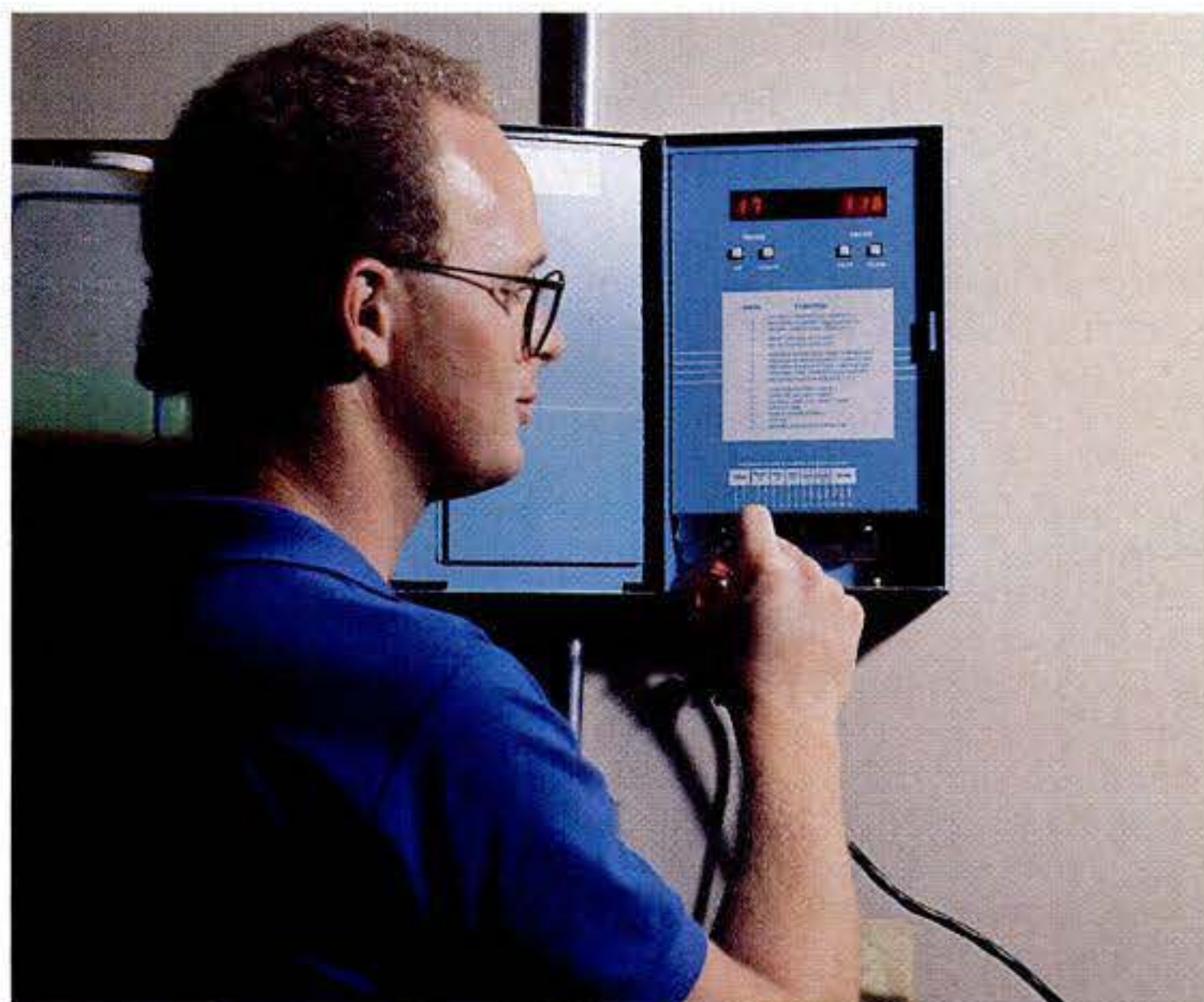
Ultem, a G.E. polyetherimide, makes Plexvent (above) and Ultravent piping heat resistant and noncombustible.

Automate your heat pump

A new version of Honeywell's programmable Chronotherm heat-pump thermostat uses a so-called Adaptive Intelligent Recovery algorithm to maximize both comfort levels and energy savings, says the company. The Chronotherm III automatically calculates when to operate the heat pump to reach the desired temperature at the programmed time, says Honeywell. This minimizes use of backup resistance heat. Claims for energy cost savings range from 10 to 41 percent for heating and 7 to 33 percent for cooling. Honeywell, 1985 Douglas Dr. N., Golden Valley, Minn. 55422. Price: \$235–\$265, installed.—*T. O. B.*



Chronotherm III detaches from wall for programming. Four modes are shown on LCD: Wake, Leave, Return, and Sleep.



With feedback from three heat sensors (being wired above), Pro-Temp controls water-heater thermostat via a relay.

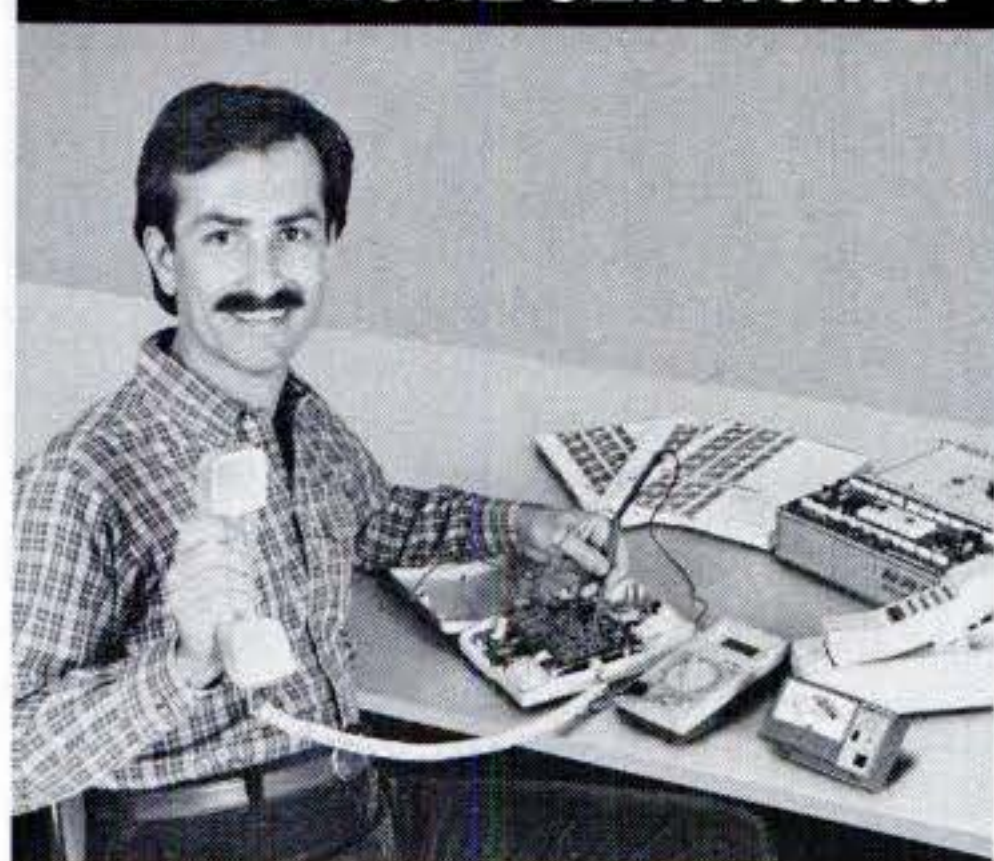
Water-heater brain

Using three sensors, a microprocessor-controlled analyzer/controller, and a thermostat relay, the Pro-Temp 8000AT controls a recirculating water heater according to usage patterns to save energy, says Fluidmaster (Box 4264, Anaheim, Calif. 92803). Every half-hour on seven-day cycles, the controller monitors and memorizes hot-water usage by measuring the temperatures of exit water, stored water, and water returning from the building. Pro-Temp is intended for multi-family dwellings.—*T. O. B.*

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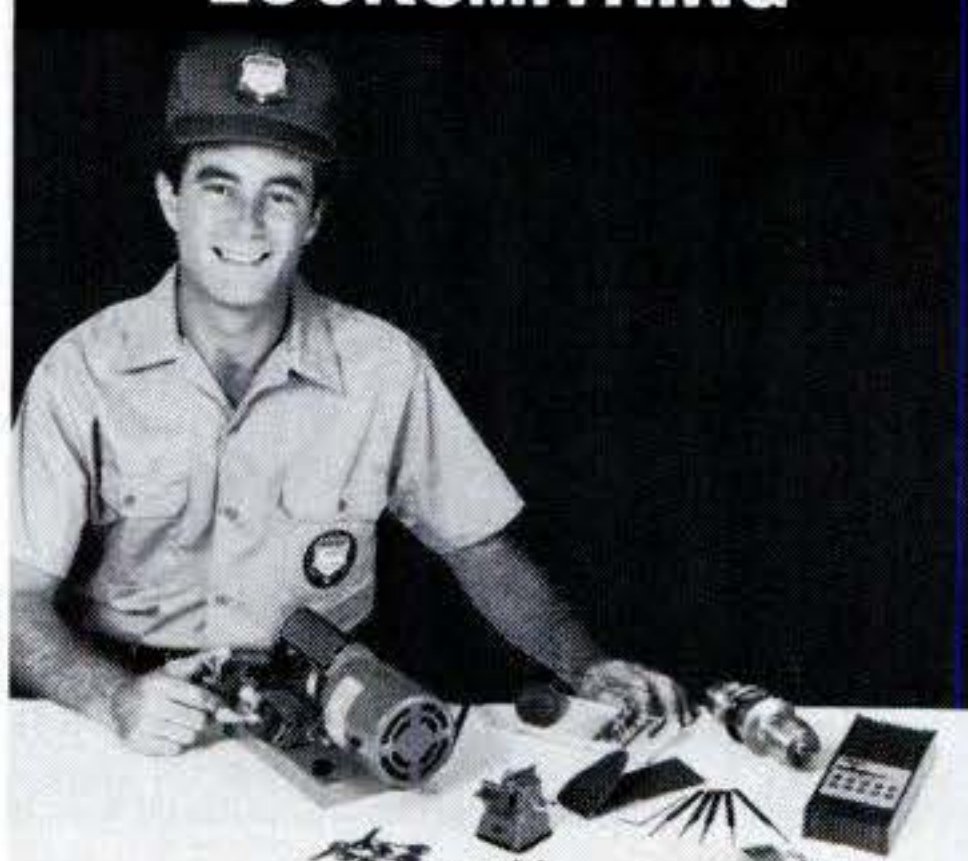
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technology is here, with opportunity everywhere for the skilled technician. NRI trains you to install, repair, and service even the most advanced electronic phones.

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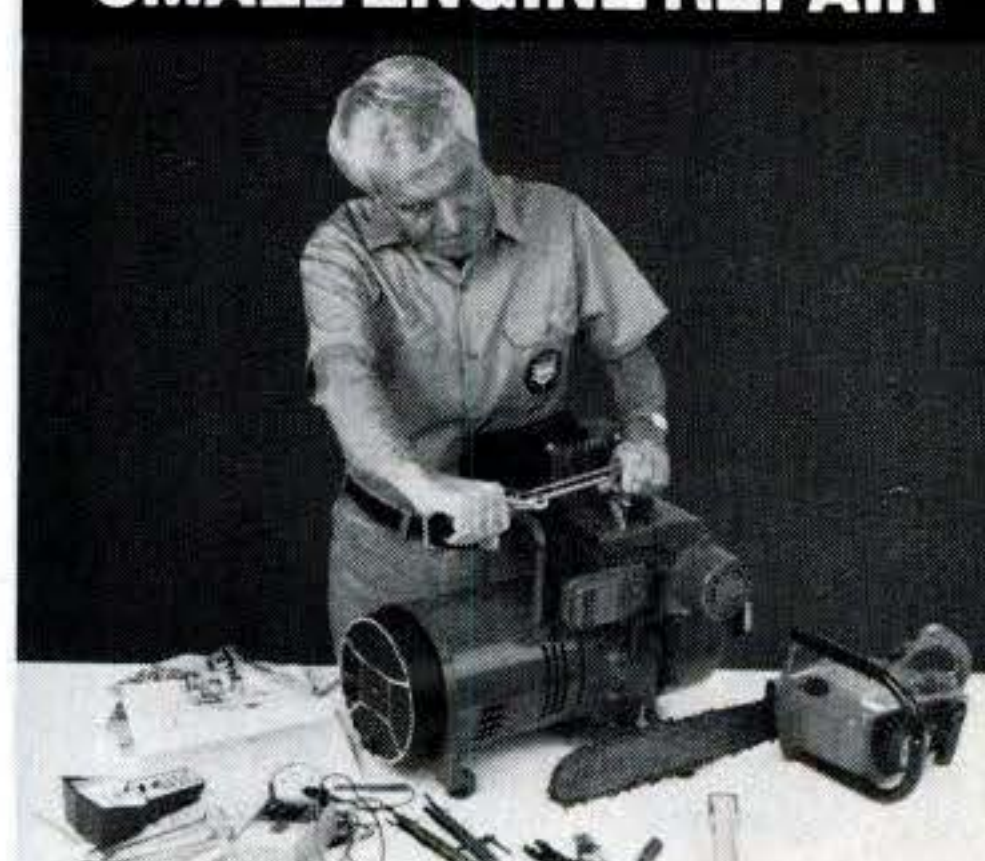
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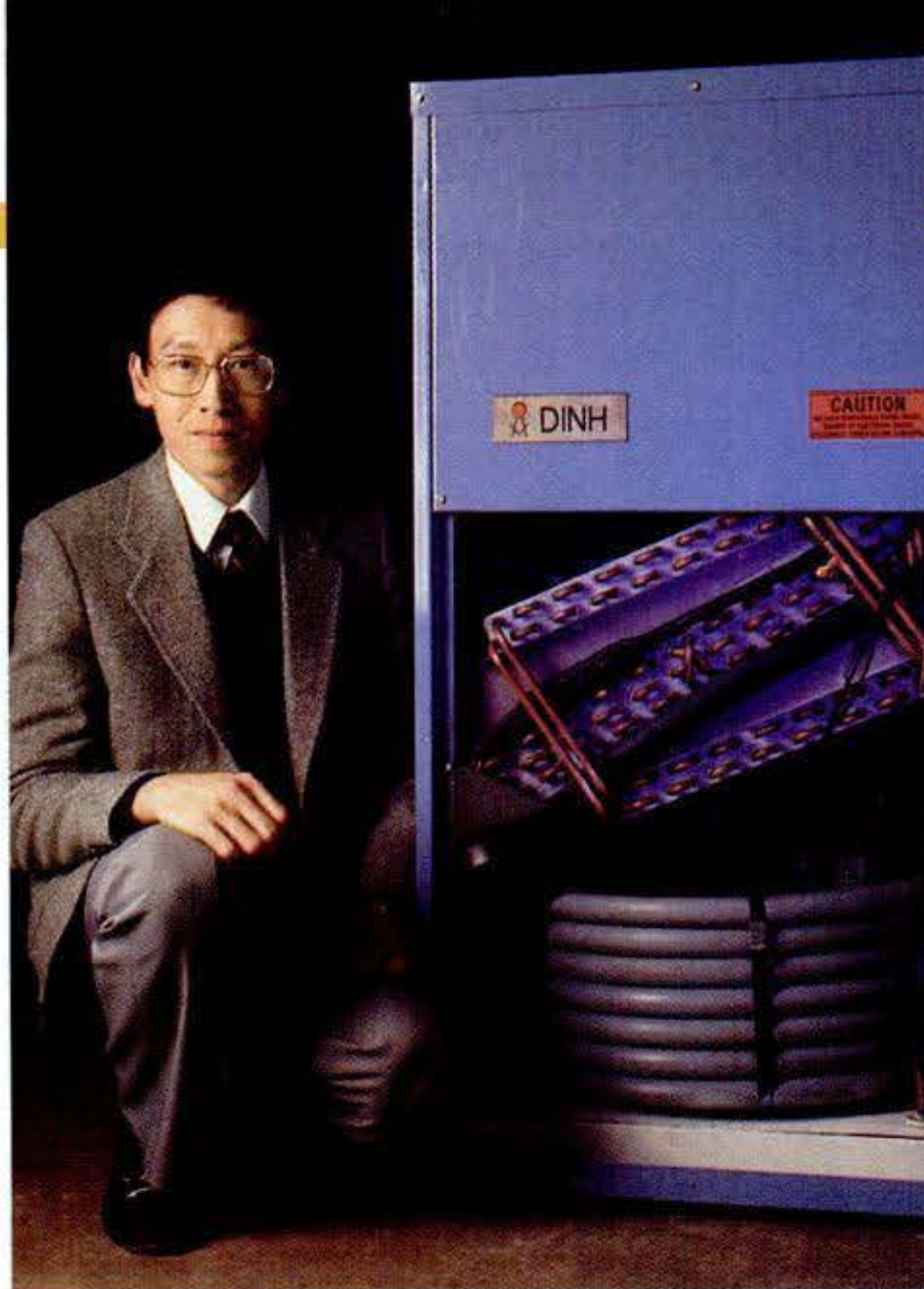
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Heat pipes for all seasons

By CHERYL M. FIORILLO



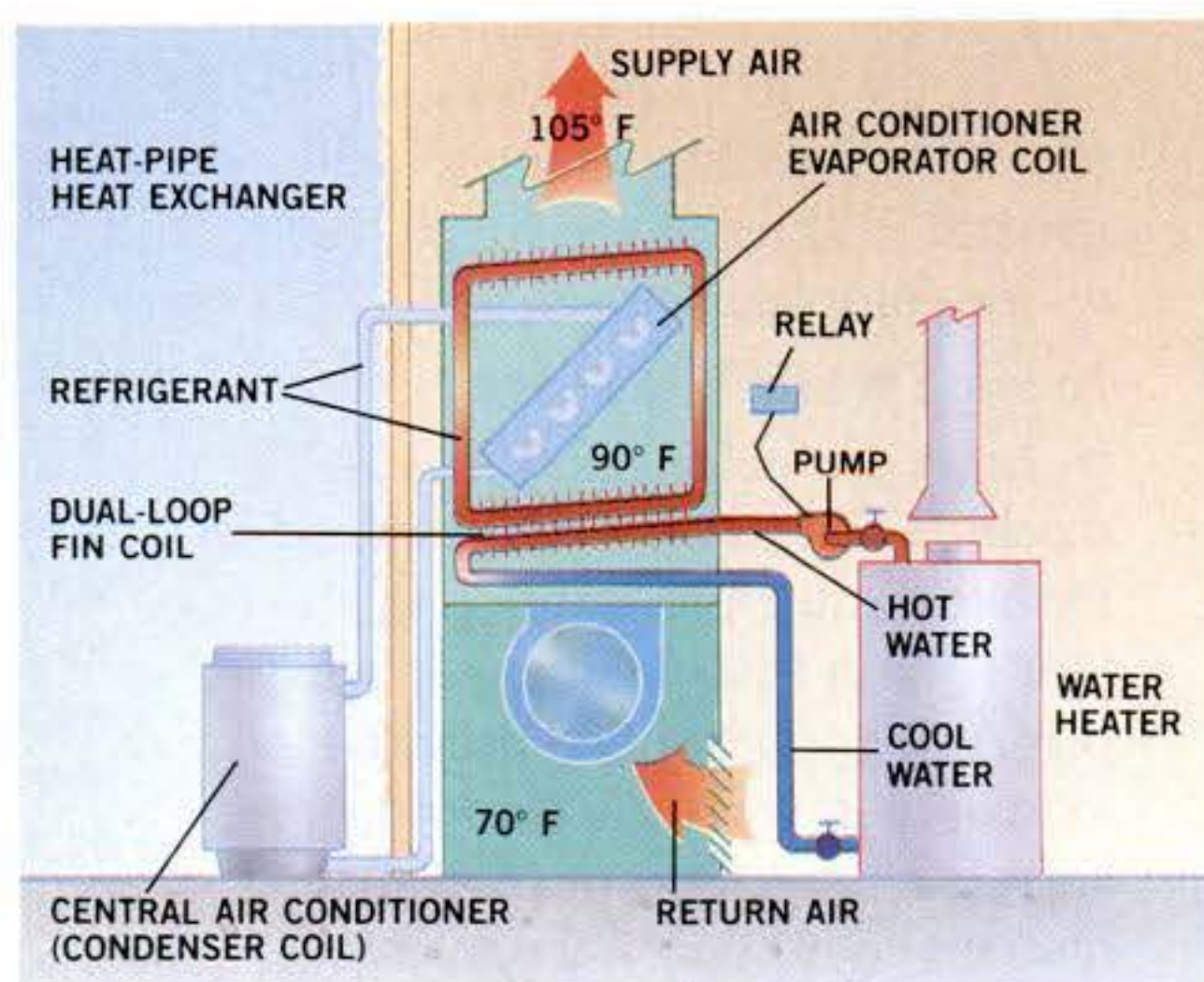
Inventor Khanh Dinh poses with his dehumidifying air conditioner based on his "Z"-Coil heat-pipe heat exchanger. Dinh's "Z"-Coil, developed under contract with NASA, received the 1987 Energy Innovation Award from the Florida Governor's Energy Office and a 1987 Special Award for Energy Innovation from the U.S. Dept. of Energy. The Dinh heat-pipe heat exchanger, a gas water heater, and a central air conditioner work together to form an all-season comfort machine (drawing below). In winter (shown) hot water from the water heater passes through the water loop of the dual-loop fin coil. The other loop is a series of heat pipes filled with refrigerant. Return air from the house blows across the fin coil, and the heat from the hot water is transferred to the refrigerant in the heat pipes, causing it to boil. The gaseous refrigerant rises to the top of the heat-pipe heat exchanger, where it condenses, releasing its latent heat to the air flowing over. The warm air, now at about 105° F, is distributed to the house. In summer the heat-pipe heat exchanger precools the return air before it reaches the air conditioner's evaporator coil. Thus, cooler air flows over the evaporator, causing it to dehumidify more effectively. Condensing refrigerant at the top of the heat exchanger adds a little heat to the supply air so that it is a comfortable temperature.

I thought I was in big trouble," 38-year-old Khanh Dinh says, chuckling at the memory of three official-looking men approaching his Gainesville, Fla., home. But the inventor—who fled his native Vietnam with his wife, Hong, two small daughters, and little else two days before the fall of Saigon—was in for a surprise. The three visitors were engineers from the NASA-Kennedy Space Center who wanted to offer him a technology-transfer contract to further develop his use of heat pipes in air conditioners.

You may remember Dinh's invention, dubbed the "Z"-Coil, which *POPULAR SCIENCE* reported on last year [Nov. '87, Dec. '87]. Its premise is to make air conditioners better dehumidifiers by using a heat-pipe heat-exchange system to cool the air delivered to the evaporator coil. That same system, when coupled to a water heater, also can be applied to home heating (see diagram).

Dinh's patented invention uses heat-pipe technology developed by NASA for the space program. A heat pipe transfers heat efficiently from one place to another as a working fluid inside continuously evaporates at one end, rises to the other, and condenses there, releasing heat.

Dinh, who had researched heat pipes at NASA's Southern Technology Ap-



plications Center, built an air conditioner/dehumidifier using heat-pipe technology for the Florida Solar Energy Center. Engineers from the Kennedy Space Center came upon Dinh's machine, taking note of the heat pipes.

"They traced it back to my place," says Dinh. "But rather than give me trouble, they gave me a contract." So Dinh refined his "Z"-Coil and married sophisticated NASA technology to the average air conditioner.

Dinh's copper heat pipes transfer heat quickly and easily because they are lined with microgrooves that increase the surface area of the pipes. The grooves also act as a wick for the liquid refrigerant, replacing the wick material used in many heat pipes. They are more efficient and cost effective than a wick system.

The benefit of the Dinh "Z"-Coil is felt primarily in humid environments during the cooling season (see caption). Because the heat pipe uses no energy, and because the same piece of equipment can be used for both heating and cooling, homeowners can save money while they are conserving energy.

Dinh is consumed with a passion for energy conservation. "Truly, my interest is to save energy for the world," he says. His work in solar energy is what first attracted the attention of the Florida Solar Energy Center and then NASA, and resulted in the birth of the "Z"-Coil. Dinh is also actively involved in an organization that plans to implement solar energy in technology-starved countries. "After all," he says, "the sun shines everywhere." **PS**

Modulating burner: no flame, efficiency gain

Most gas burners produce little jets of flame. But if you could squeeze gas through tiny enough holes, you'd get a more even and so more efficient burn. Alzeta Corp.'s Pyrocore fiber-matrix burner does this, straining the fuel-air mix like a sponge to produce such a low burn it appears almost flameless.

The Pyrocore burner is part of an efficient condensing hydronic heating system that Teledyne Laars (Moorpark, Calif.) is developing. When Teledyne Laars engineers first designed the system, they decided for simplicity of design that the condensate should drip off the bottom of the heat exchanger. But in conventional boilers, the burner sits below the heat exchanger—or right in the path of the corrosive condensate in Teledyne Laars' configuration.

The solution was to use the Pyrocore burner. "The fiber-matrix burner's efficiency and smaller size let us invert the burner and put it *above* the heat exchanger," says Larry Brand of the Gas Research Institute, a supporter of the system's development.

In the Teledyne Laars system the gas and air are mixed, then forced through the burner by the variable-speed blower. The fiber-matrix burner, made of a porous ceramic material, then strains the gas mix into tiny amounts that burn evenly. "The combustion occurs so close to the ceramic-fiber surface that there is no visible flame. What you see is the surface glowing orange," says Wayne Krill, vice president of marketing for Alzeta (Santa Clara, Calif.).

The two-stage burner fires downward toward the heat exchanger, just one inch away. The heat exchanger then extracts the heat, delivering it to water circulating through the house. The system has an annual fuel utilization efficiency (AFUE) of above 90 percent. The water vapor in the hot flue gases condenses on the bottom row of the heat exchanger tubes, is collected, then drained outside.—

Nancy Negovetich

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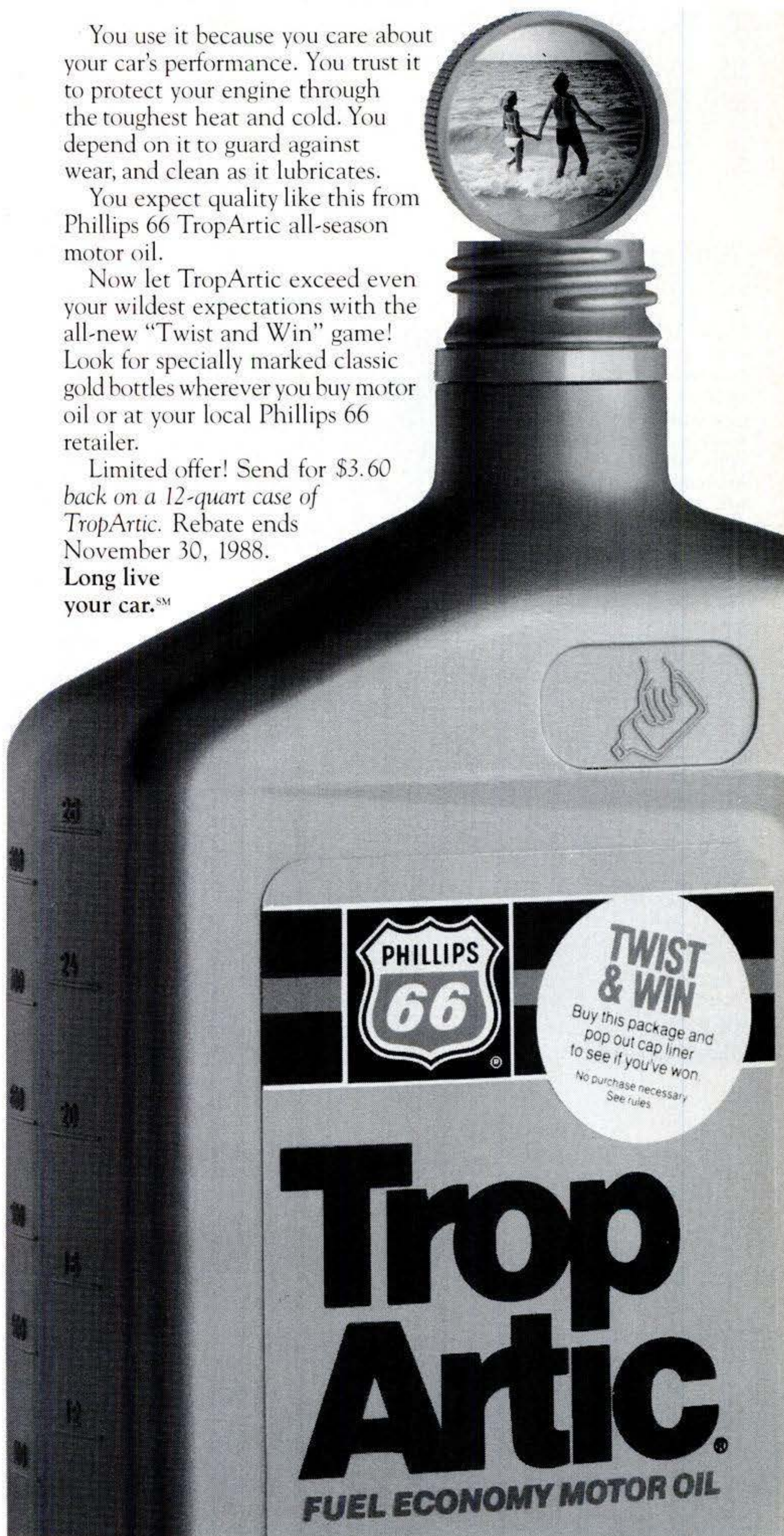
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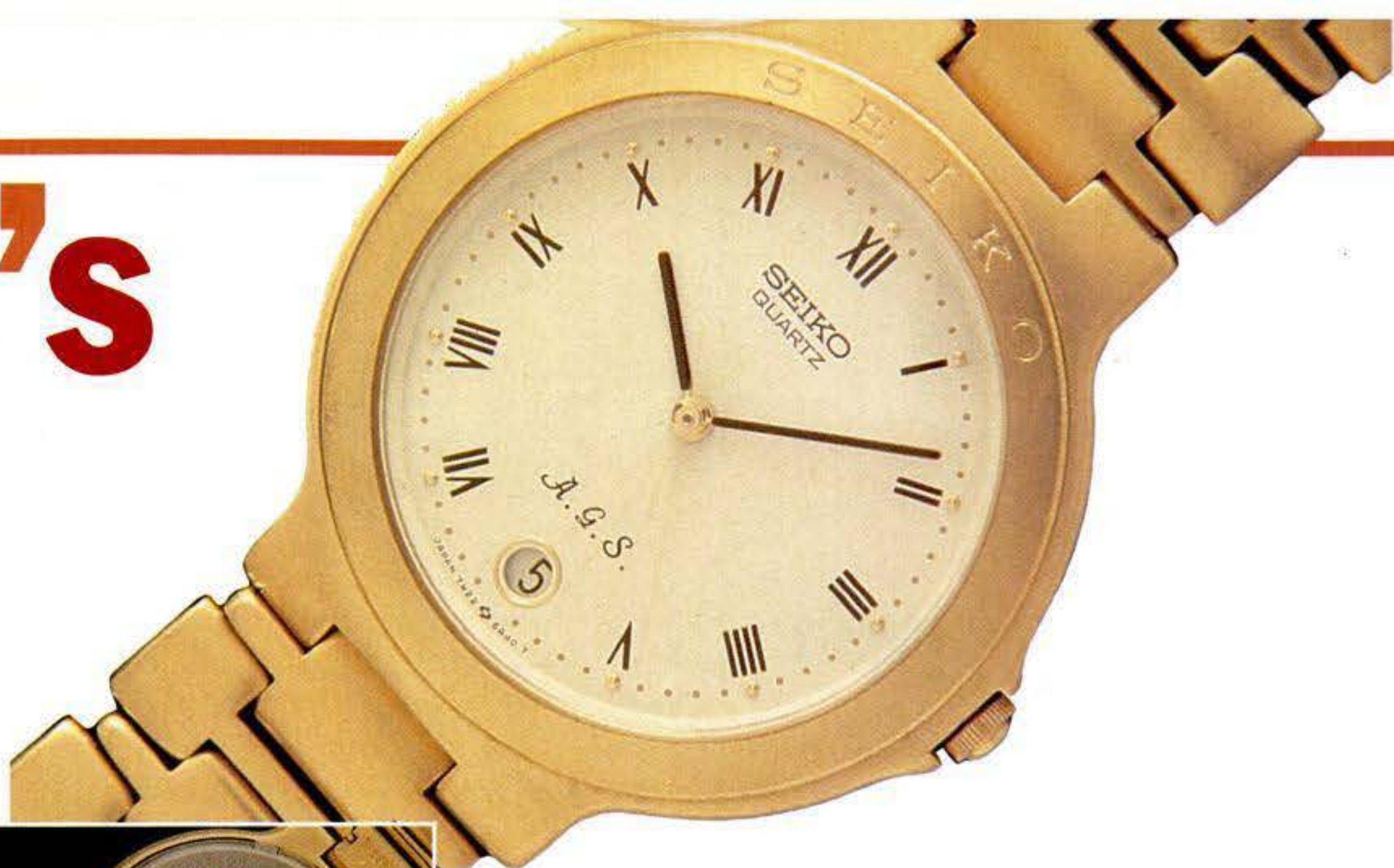
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BY DAWN STOVER

What's New

Runs by hand ►

This watch doesn't need a battery or solar cell. The AGS (Automatic Generating System) quartz watch uses the wearer's wrist movements to operate the world's smallest generator, says Seiko. The rotor spins at up to 100,000 rpm, and the watch stores enough energy to run for 72 hrs. after it's removed. Prices for the analog calendar models start at \$375.



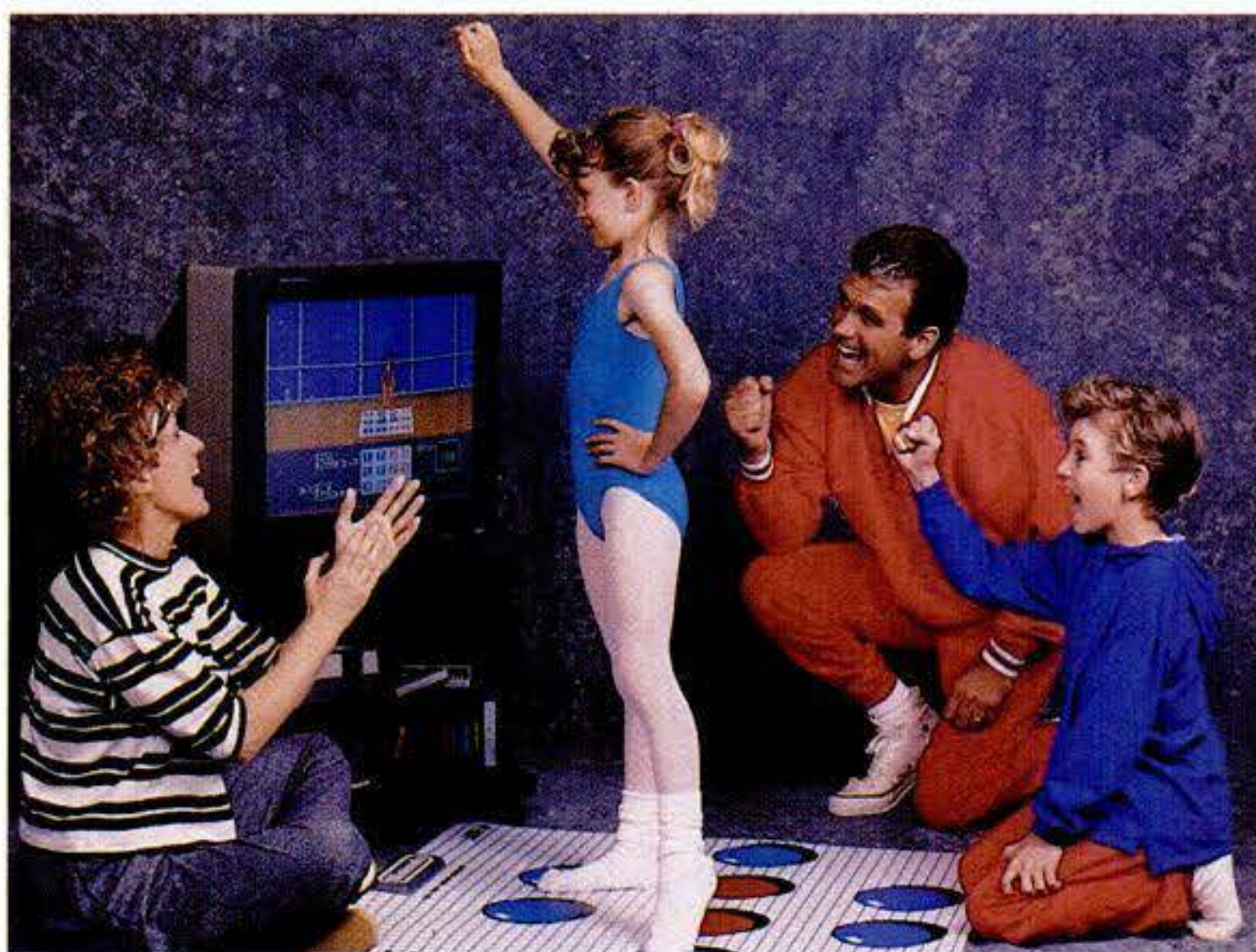
Vending carousel ►

Made by the French company Forenia, this automated kiosk can be installed outside a store (for nighttime shoppers) or inside (to prevent shoplifting of small items like compact discs). Users feed credit cards into a command module that controls up to six carousels.



► Interactive mat

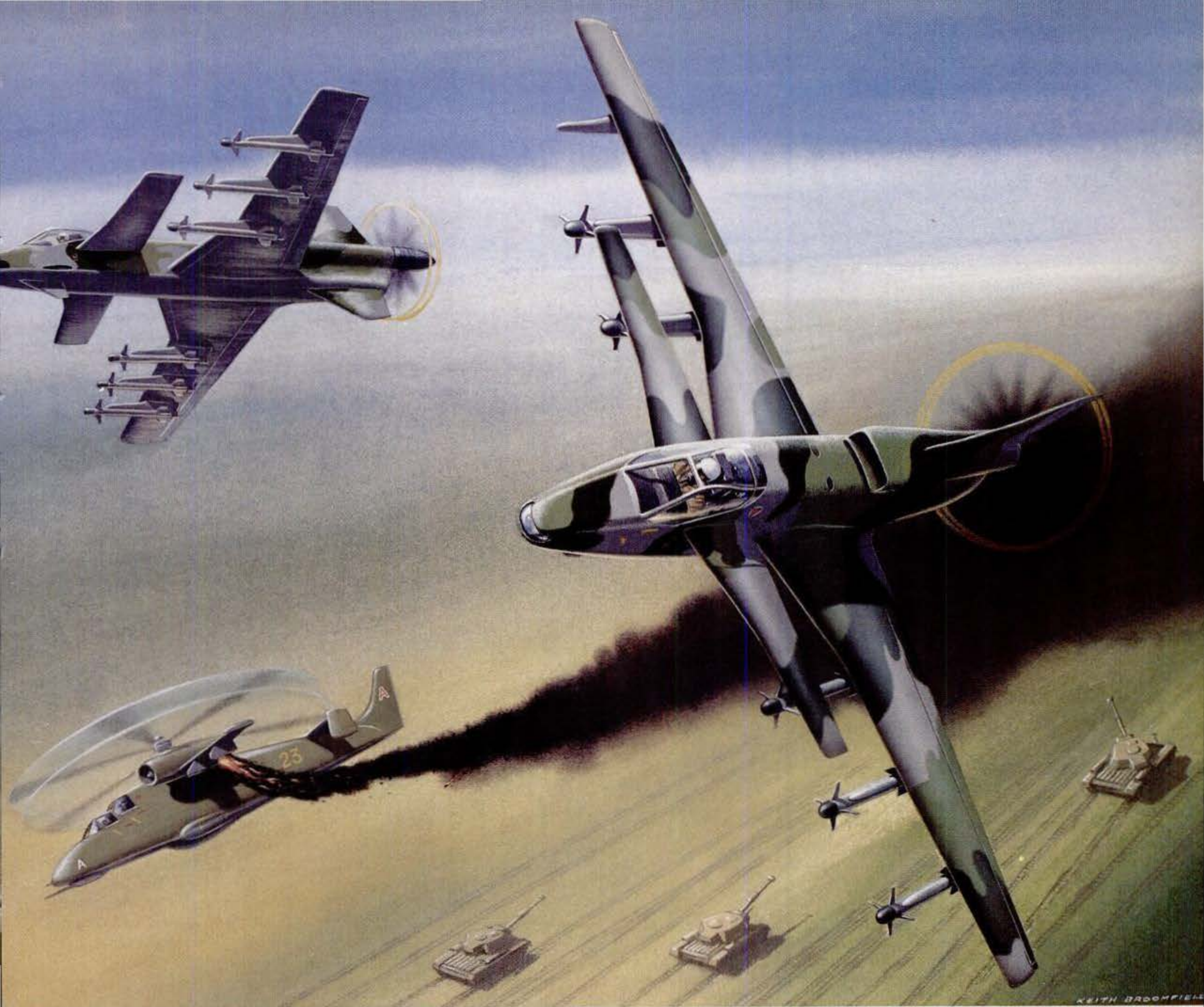
Nintendo's Power Pad lets this video-game player use her feet to control on-screen characters. It's part of the Power Set, along with a control deck, two handheld game controllers, a light gun, and three software titles. The set's average price is \$149.



► Updated Audi

Audi 100/200 sedans and wagons have the same basic shape as the 5000 models they replace; but the interiors (above) have been redesigned, with a cockpit styled after the 80/90 series. In automatic models, the transmission now shifts through a gated pattern for easier indication of gear position.





Agile aircraft ▲

Artist's concept of British Aerospace's Small Agile Battlefield Aircraft (SABA) shows a large canard, contrarotating prop fans, and two rudders—dorsal and ventral. Designed to attack low-altitude targets like combat helicopters, tilt-rotor aircraft, and cruise missiles, SABA must turn 180° in 5 sec. at combat speeds.



Hybrid train ▲

A linear motor propels the Limtrain along a center rail, but the train is supported by iron wheels, rather than by magnetic levitation. It's the first motor car of its type in Japan, says Mitsubishi Heavy Industries, the builder. The Limtrain carried passengers on trial runs at the '88 Saitama Expo in Kumagaya City.

Special delivery ►

Push a button, and the remote-controlled Letter Sledder extends into your car, so you can easily retrieve your mail. Two models are sold: electrically wired (\$200) or solar powered (\$250). They fit any mailbox. Todd Powers Associates, 825 Harper Dr., Algonquin, Ill. 60102.



What's New PHOTOGRAPHY



Motorized zoom 35 ▲

A follow-up on Pentax's world's first point-and-shoot camera with a 35–70mm powered zoom lens, the IQZoom70 provides a greater range of shutter speeds (from $\frac{1}{5}$ to $\frac{1}{250}$ sec.), an on-off flash switch, and a redesigned body. List price: \$437.

Micro-mini tripod ▼

The Photo-Elf micro-tripod can be left attached to a 35mm camera and still fit into the camera's soft case. With the legs folded it's only $\frac{1}{4}$ in. thick. It's useful for self-timer shots when you want to get into the picture. Elf, Inc., 2229 E. Burnside No. 77, Gresham, Ore. 97030; \$15.



More Maxxum SLRs ▲

Minolta has added to its Maxxum line the 3000i, a light, simple, single-lens reflex, and the 7000i, an extremely sophisticated design that is the first to use interchangeable electronic chips for varying modes. Price of the 3000i is \$486; the 7000i with the same 50mm f/1.7 lens is \$838.



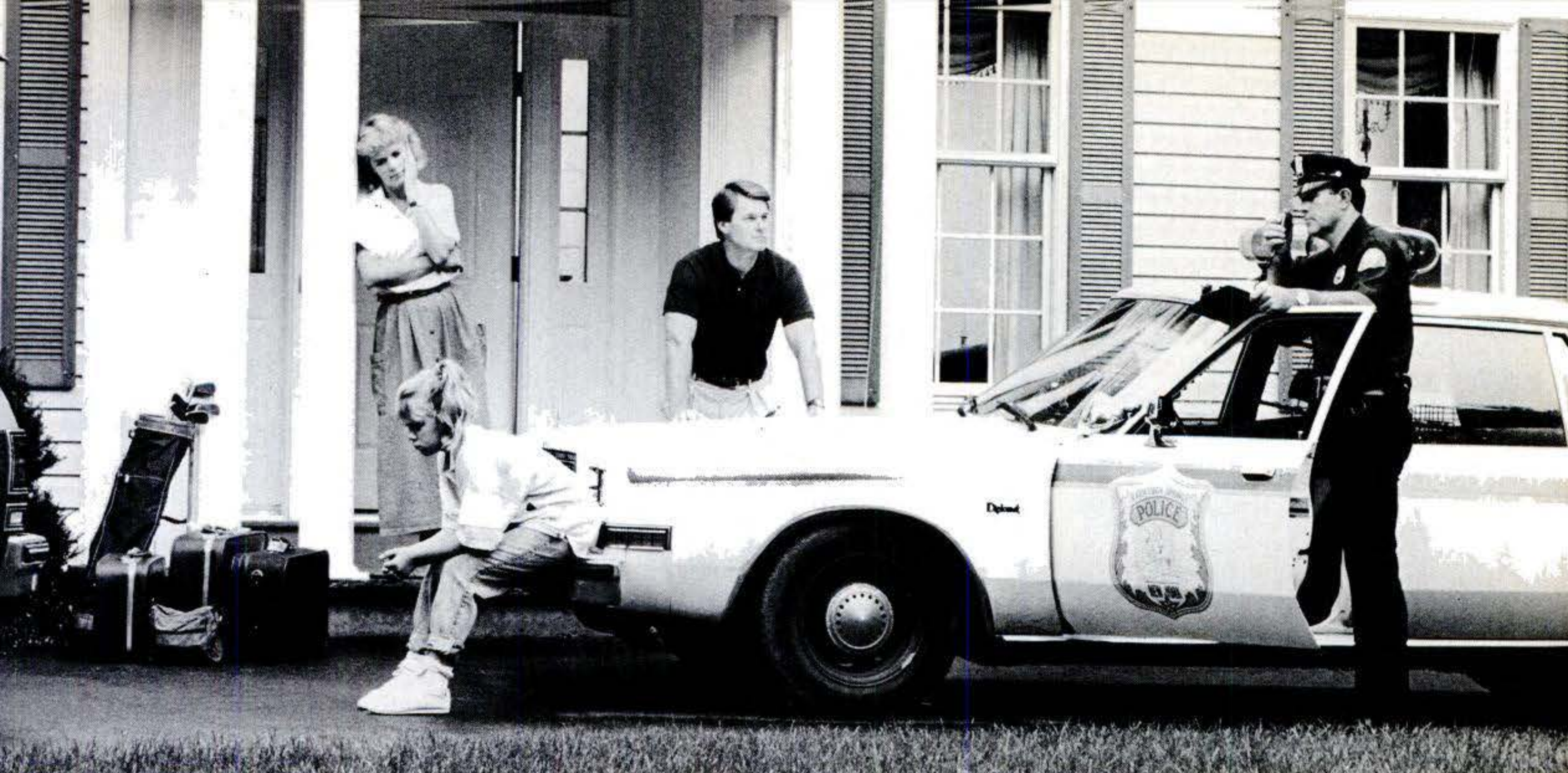
◀ Compact cat

Designed to work with the Canon EOS camera, this manual-focus 600mm f/8 catadioptric (mirror) lens from Sigma Corp. of America is only 4.8 in. long, weighs just 29 oz., and focuses to 79 in. It comes with five filters and a lens hood, case, and strap. List price is \$517.



Multi-mode zoom 35 ▲

The Canon Sure Shot Zoom, equipped with a manually operated 35–70mm zoom lens, offers three exposure modes: automatic, daylight flash, and slow shutter. In this last mode the flash will not fire, making it possible to get natural images of fireworks, sunset silhouettes, and the like. A lithium battery powers the auto-everything camera. Price: \$460.



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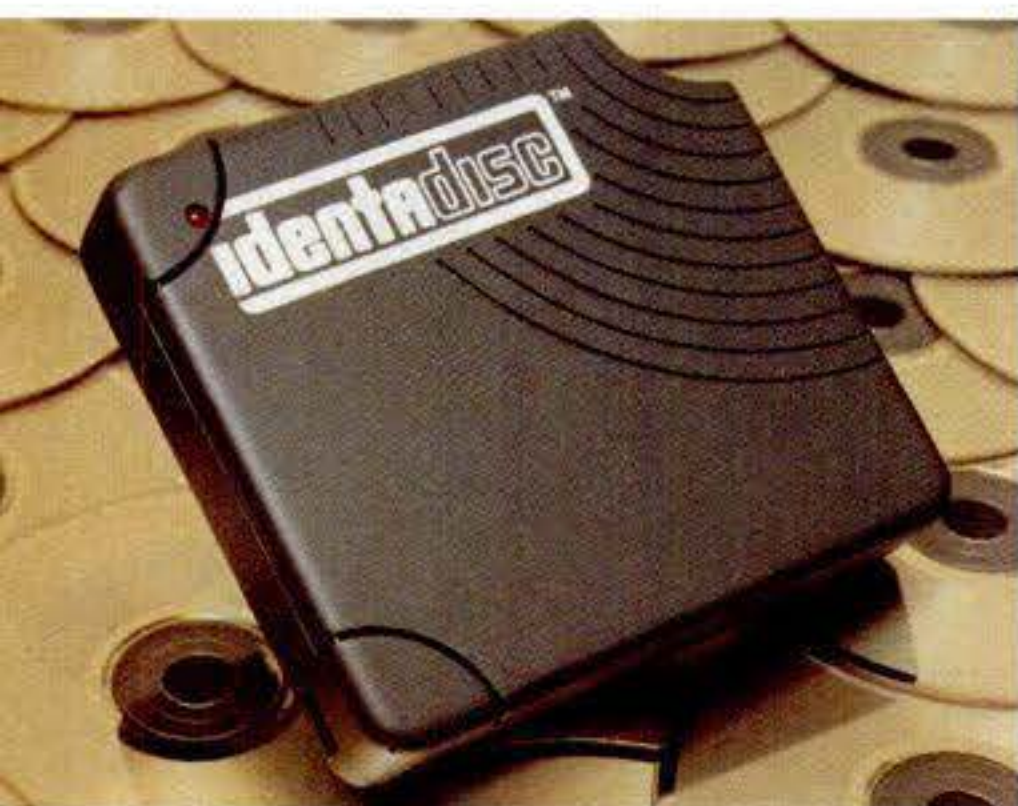
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What's New ELECTRONICS

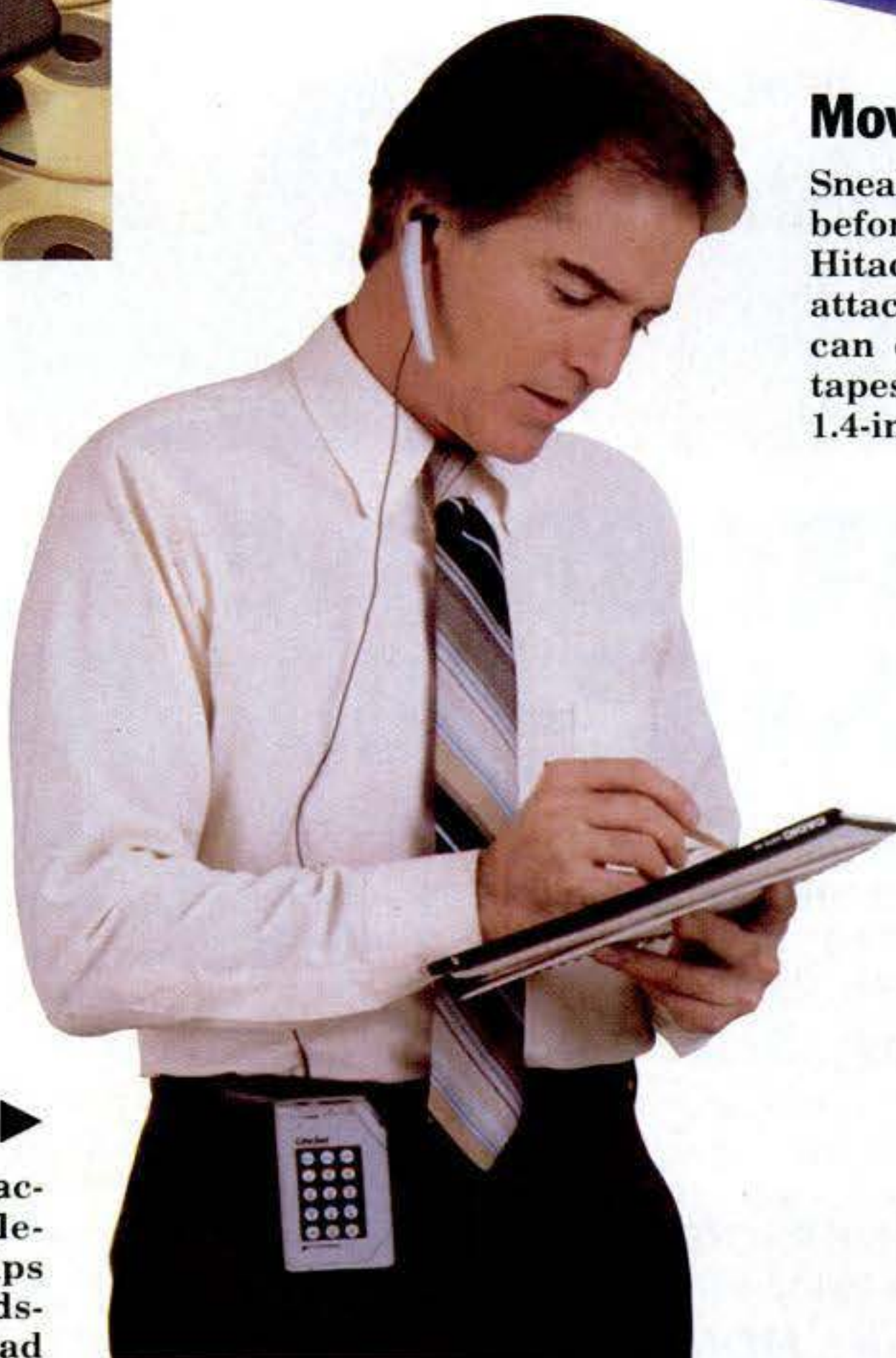


CD marker ▲

Put your valuable CD, CDV, CDI, or CD ROM in IdentaDisc and close the top. Seconds later your initials and Social Security number are permanently embedded in the CD's plastic. Hi-Pro-Tech, Box 1357, Lansdale, Pa. 19446; \$50.

No hands, no wires ►

Walk and talk. The Hammacher Schlemmer & Co. telephone is cordless and clips around your ear for hands-free operation. The dial pad with rechargeable battery pack clips to your belt. The price of the telephone is \$215. Address: 147 E. 57th St., New York, N.Y. 10022.

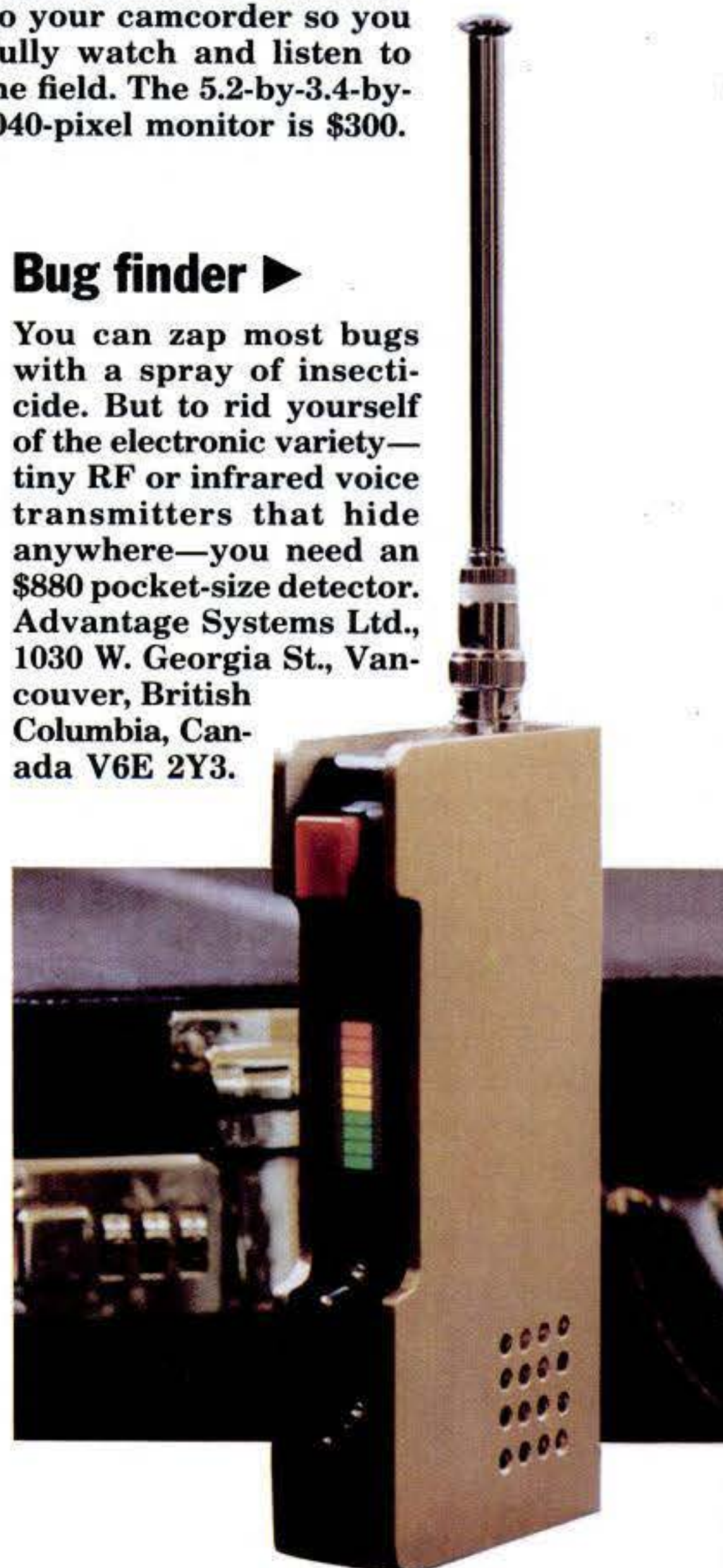


Movie checker ▲

Sneak a critical peek at your videos before you pack up and go home. Hitachi's 2.7-in. color LCD monitor attaches to your camcorder so you can carefully watch and listen to tapes in the field. The 5.2-by-3.4-by-1.4-in. 94,040-pixel monitor is \$300.

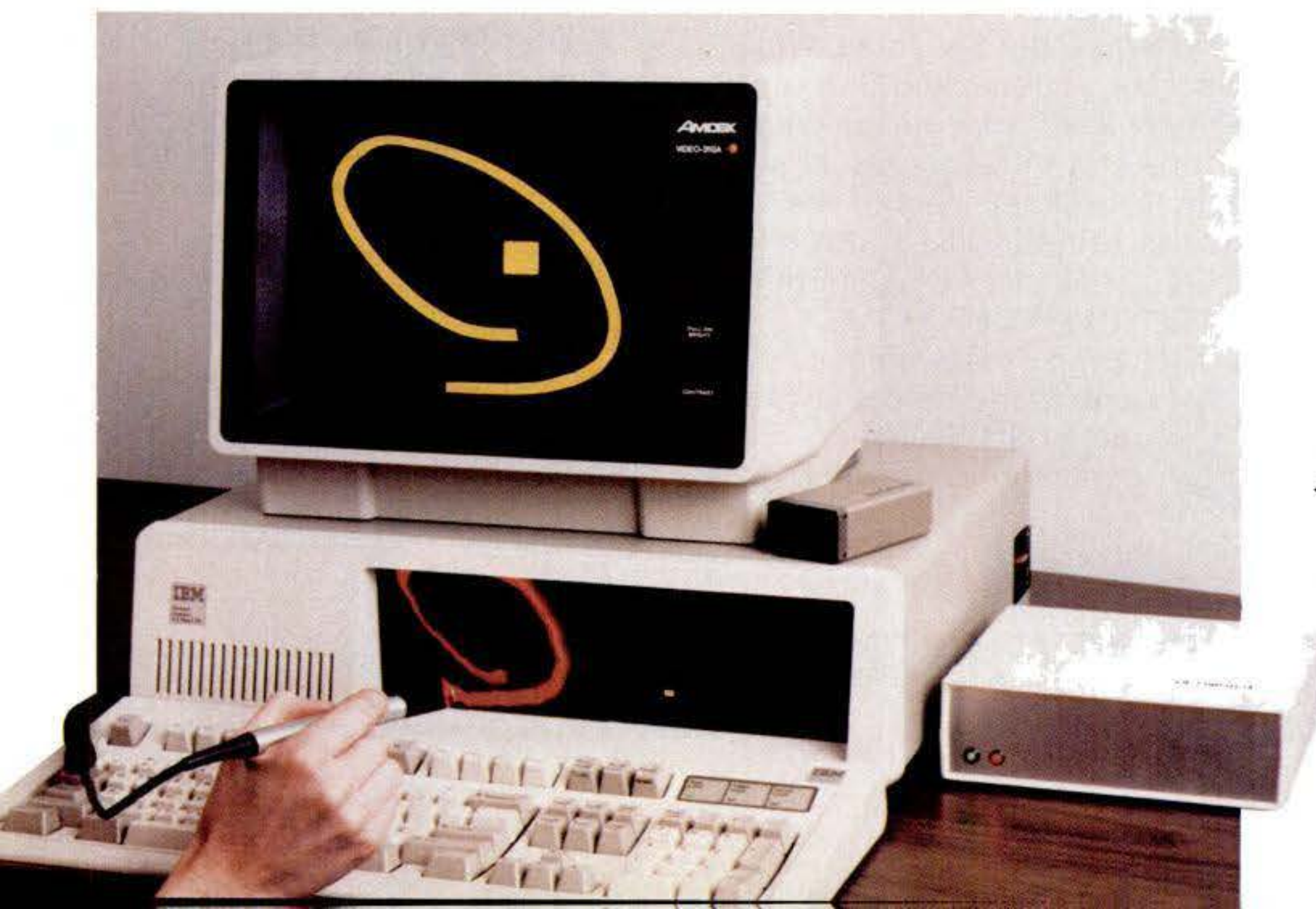
Bug finder ►

You can zap most bugs with a spray of insecticide. But to rid yourself of the electronic variety—tiny RF or infrared voice transmitters that hide anywhere—you need an \$880 pocket-size detector. Advantage Systems Ltd., 1030 W. Georgia St., Vancouver, British Columbia, Canada V6E 2Y3.



◀ No-contact mouse

An image sensor at the computer tracks the position of the hand-held Optimouse. Move the wandlike mouse in the air—as if you're aiming at the screen—and the cursor follows. It's \$2,800 from ISCAN Inc. (125 Cambridgepark Dr., Cambridge, Mass. 02238).



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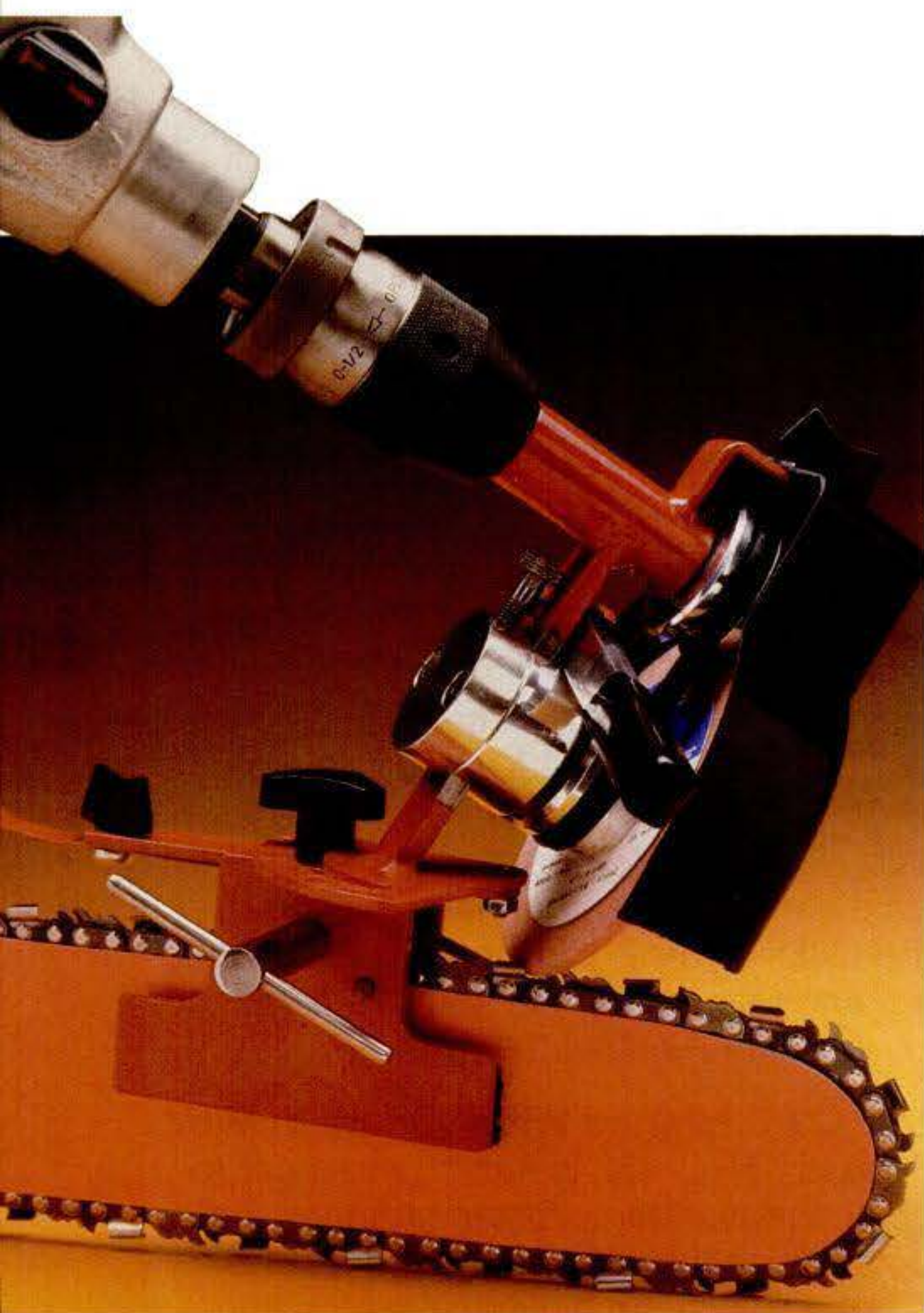
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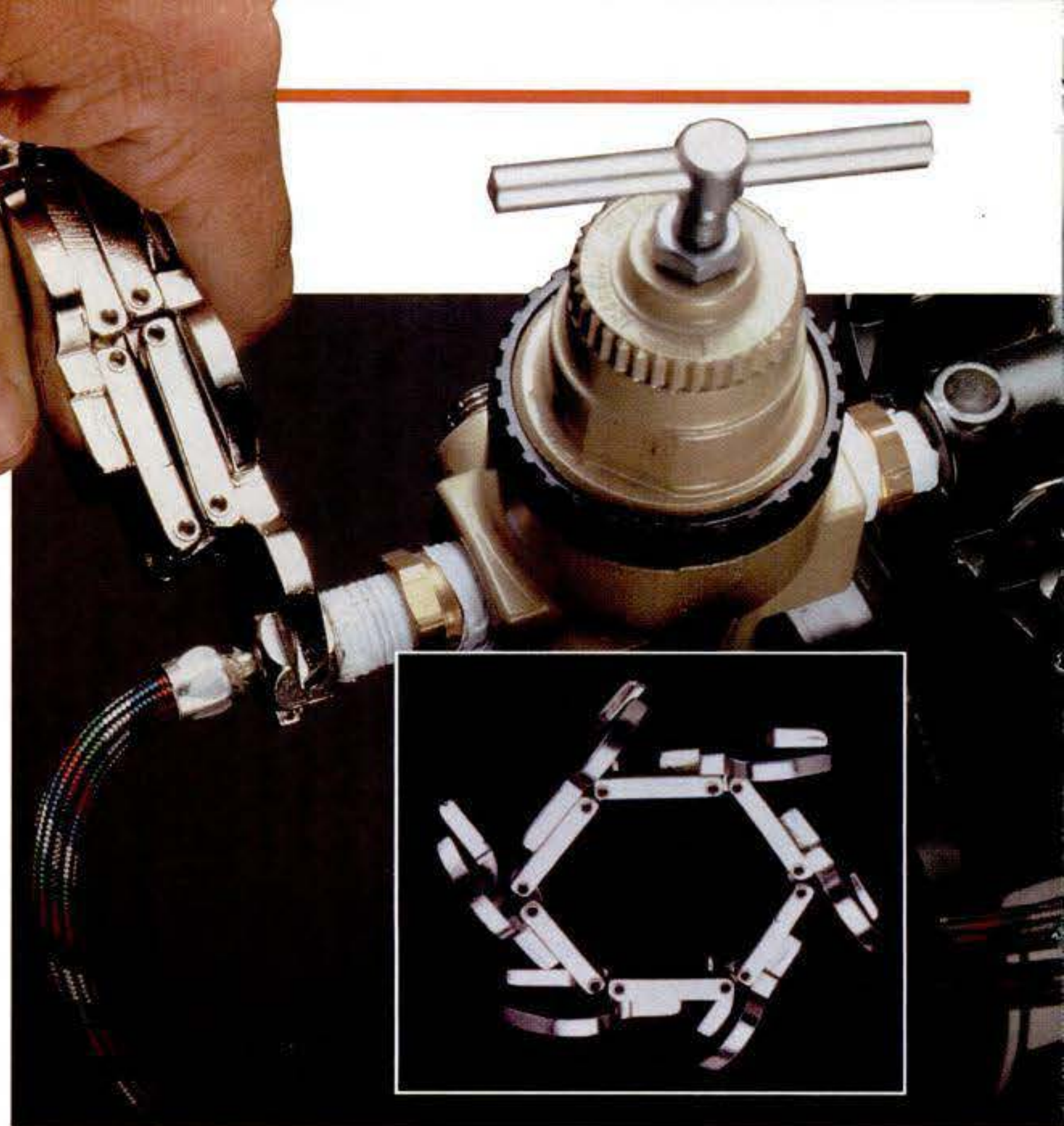
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What's New TOOLS



◀ In situ sharpener

With the belt-driven Martek sharpener hitched to your $\frac{3}{8}$ -in. drill, you can renew the teeth of a saw chain without removing the chain from the guide bar. You advance the chain by hand, locating each cutter against an adjustable stop. First you grind all left-angled cutters, then all the right-handers. Martek Ltd., Box 20, Redruth, Cornwall TR15 2UF, England; \$69.



Six pack ▲

Always seem to grab the wrong-size wrench? When you pick up Chain Tool's Chain Wrench you have six chances to get it right. Five of the six open-ended wrenches fold down, forming a handle for the one that fits. Available in two size ranges: $\frac{1}{4}$ to $\frac{7}{16}$ in. (\$19) or $\frac{1}{2}$ to $\frac{13}{16}$ in. (\$20). Chain Tool Co., Box 216, N. Salt Lake, Utah 84054.



Mystery saw blades ▲

Dyanite is carbide but not tungsten, and that's all DML is saying about its new compound for cutting edges. Dyanite saw teeth stay sharp from 20 to 1,100 percent longer than standard carbide teeth, it's claimed. DML Inc., 1350 S. 15th St., Louisville, Ky. 40210.

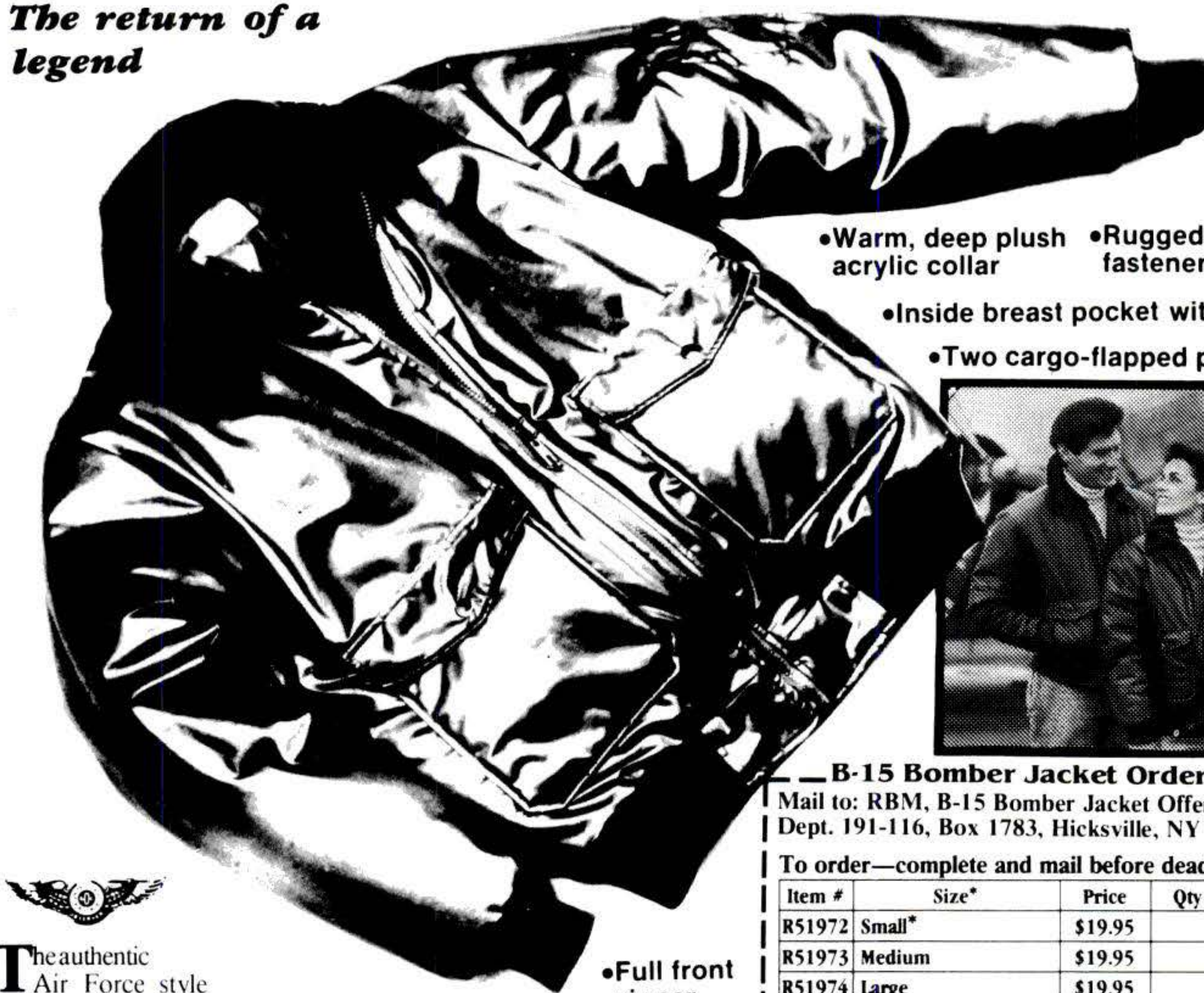


Metal slicer from Down Under ▲

You can zip through sheet metal up to $\frac{1}{16}$ in. thick with an Australian-made cutter called Excalibur. The head attaches to an electric or pneumatic drill and handles easily for straight or curved cuts, claims the exporter: Fahelen Pty. Ltd., 1/29 Warraba Rd., Narrabeen 2101, Sydney, Australia.

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Kit house—new tech

[Continued from page 72]

with a twelve-foot wall section that they can't get into the house."

The Ademmers broke ground in late August, and Jerry and David Ademmer laid the block foundation. "It was letter perfect," says Scott Gerber of Miles. The kit arrived on November 12th, a Thursday. David took the day off work. (In all, he took only five days' vacation to work on the house. But it pretty much ate up his free time when weather permitted working, he confirms.)

On delivery day the sky was clear, the ground was dry, and the temperature reached a balmy 60 degrees F. The preassembled framing panels went up fast.

On the second day, with the two dads working, they hit a snag. "One framing panel wasn't square and it threw off a corner," David says.

The only real framing problem they had—indeed the biggest problem of all (aside from the weather)—was the angled stairway (see plan). Miles did not panelize the framing around the stair. "Too many site variables," Gerber explains. So like the Rafters, our stick-building couple in Pennsylvania, the Ademmers had to cut 2×4s to size and deal with odd angles in the installation. That was the hard part. "Blueprints didn't explain it well," David wrote in the log they kept daily. "I don't think the Miles people knew exactly how to do that stairway," he confided to me later. "It was our first," Gerber admits.

On November 18th the Ademmer team discovered another problem: The floor trusses weren't square. Not a standard component for a Miles kit, the company bought them from a local fabricator. "It wasn't a serious problem," says Gerber, "but the Ademmers didn't know what to do." David called Miles and was instructed how to shim to square the ends.

By November 23rd the second-story wall framing was up. "It's finally starting to look like something, and I want to work on the house even more," David wrote in the log. With the Thanksgiving weekend coming, he knew he'd get in four good days.

The weather had other ideas.

On November 28th, the Saturday after Thanksgiving, freezing rain was falling. "We chipped ice off the studs for two hours, worked an hour, then gave up," David laments softly.

The next day they put a propane heater in the lower level and cranked on the heat to melt the ice, then worked 12 hours under numbing conditions.

But by this time Chris was beginning to see her dream house materialize. "It was so neat to walk around

in the upstairs and tell where the rooms are and how big they're going to be," she wrote on November 29th.

December 5th: Another problem. It was time to put up the roof trusses, which were numbered, but inexplicably their blueprints didn't have the number codes on them. The builders guessed which went where, called it wrong, and had to add some bracing to a truss as a result.

"Taking time off work tomorrow so that I can close off the roof because of coming rain and snow," David noted in the log on December 6th. He called on two additional helpers to get the job done fast. And they did. "As I put up the last sheet of roof sheathing it started raining," David recalls.

Soon after Christmas winter arrived with a vengeance. "Some days it was twenty below with strong winds," David tells me. They logged only 9½ hours in January. February saw some improvement. By mid-month they were working about half the days, albeit with gloves and layers of clothes.

In March the weather improved, and the Ademmer team began the final phase of exterior work: the siding and trim. Siding came primed, and Chris added another coat of gray primer.

On Sunday, March 13th, David worked for seven hours finishing the trim and siding and installing the garage doors. By the end of the day he'd completed the exterior to the point *POPULAR SCIENCE* and Miles had determined would end our "contest." Gerber added up the hours logged: 600 hours, 15 minutes.

Sweat equity

"If you were to start now, what would you do differently?" I ask David. "I'd start in the spring," he replies without hesitation. But he admits to no real regrets.

And no wonder. He and Chris have a lovely new home for which they paid about half the market value. Base price for the kit is \$45,000. They bought kitchen cabinets, carpeting, paint, and plumbing fixtures locally, so they actually paid Miles a little less, even with the interest on the construction loan. Based on what other houses in the area are selling for, David thinks the house could sell today for about \$90,000 (including a small portion of land).

Not that he'd consider that. But he is toying with the idea of building another house to sell, preferably with a partner. Now that he's got an education, would he go to the lumberyard and buy the raw materials?

"Too much work," he replies, with a hint of a grin. "I'd get another Miles kit—with panelization." **PS**

Kit house—old tech

[Continued from page 74]

uncle helped out when they had weekends free. But I was surprised how scarce my friends became once construction started. This has been strictly a weekend project. Dot and I developed a game plan, spending Monday through Friday getting prepared; then we'd charge out into the snow on Saturday and sometimes mess things up, spending the afternoon redoing things we'd done wrong in the morning.

"Sundays were always the best days. Somehow we didn't feel the Saturday pressure of 'so much to do this weekend.' But by Sunday night the site looked like a battlefield, and it was important to save some time before dark to clean up and reorganize for the next work session."

Other tips from the front:

- "If you're going to alter or add to the floor plan, do it before you start building. The nice thing about working with an outfit as well-organized as Miles is that its computer system can bang out a revised set of working drawings in no time. But it messes up all calculations if you change your mind *after* you're very far along."

- "One great boon with a kit is that it eliminates shopping, saving you hours at the lumberyard and hardware store. And because kit packagers buy in quantity, they can get the best quality in lumber and plywood. There's no comparison between what they can supply and the stuff you find in local lumberyards."

- "Find a company that's not pushy about accepting complete packages. For instance, I canceled the Miles electrical package, figuring I'd buy that locally, and we upgraded our bathroom fixtures, getting credit for the basic units that come with the Foxwood kit."

What's been the *worst* part of the experience? "The rafters!" Marty and Dorothy shout in unison. "Add up the hours we spent just building the roof," Marty continues: "Two hundred ninety-three! That's nearly half of the time we've spent on the whole house—and we haven't even applied the flashing, felt, and shingles! All those angle cuts for each rafter brace...!"

The most telling question you can put to anyone at the end of an owner-builder project is: "Would you do it again?" Marty thinks this over, then flashes an appreciative grin at Dorothy: "With a wife as supportive and helpful as mine, a guy can tackle anything. We've learned enough so that the next one would go quicker." Dorothy picks up his thought: "One thing we've learned is to start building in the spring," she says. "And we'd buy a kit with trusses," he adds. For a catalog of plans, write Miles Homes, Box 9495, Minneapolis, Minn. 55400. **PS**

Fax it

[Continued from page 64]

But to reproduce the line art in more detail than a conventional fax could provide, Shepps opted for a high-end model.

"More elaborate fax machines encode the picture with more details than just light or dark pieces of data," says Mitsubishi's Roberge. Most encode 8, 16, or 64 gray scales, depending on the model. "Also, some machines have a fine or super-fine option."

At the fine or super-fine speeds the document moves more slowly through the machine so a picture with finer vertical resolution—from a low of 100 pixels per inch up to 400—can be sent. "The trade-off for the additional gray scale and higher resolution is speed," says Roberge. "It simply takes a bit longer to send the additional information."

How do you set your fax so it matches the resolution and speed of the receiving machine? "You don't," says Roberge. "The two machines set themselves automatically."

Twisting the fax

"It's a floating office," says Herb Johnson, director of marketing services for NEC America. Makers like NEC have taken advantage of the simple-to-use shrinking fax machine to add another twist: portability. "Our customers connect the portable fax to a cellular phone and go anywhere a car, boat, or truck phone will take them," he says. "It's being put to real use by on-the-road real-estate people and insurance claims adjusters."

Other users, like Jeffrey Moses of Columbia, S.C., go to the other extreme. "I added a fax board to my IBM personal computer," he says. Made by companies like The Complete PC, the plug-in circuit board turns your computer into a sophisticated fax system with the ability to send or save disk files (see "Electronics Newsfront," this issue). "The PC lets me merge documents and graphics into my fax communications," says Moses.

But somewhere between the portable and PC-bound fax machine is a proliferation of models that include a telephone handset and additional phone conveniences such as speed dialing, memory, even built-in phone-answering capability (faxed junk mail of the future?) and photocopying.

Like personal computers, fax machines could change the way we do business. And like the early predicted uses of home PCs, they could be used for everything from faxing do-it-yourself plans to exchanging recipes. But all that will take a lot of fax sales. "You can buy what you want," says NEC's Johnson, "but you still need someone to receive those recipes." **P S**



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Waterline leak? Patch it with glue

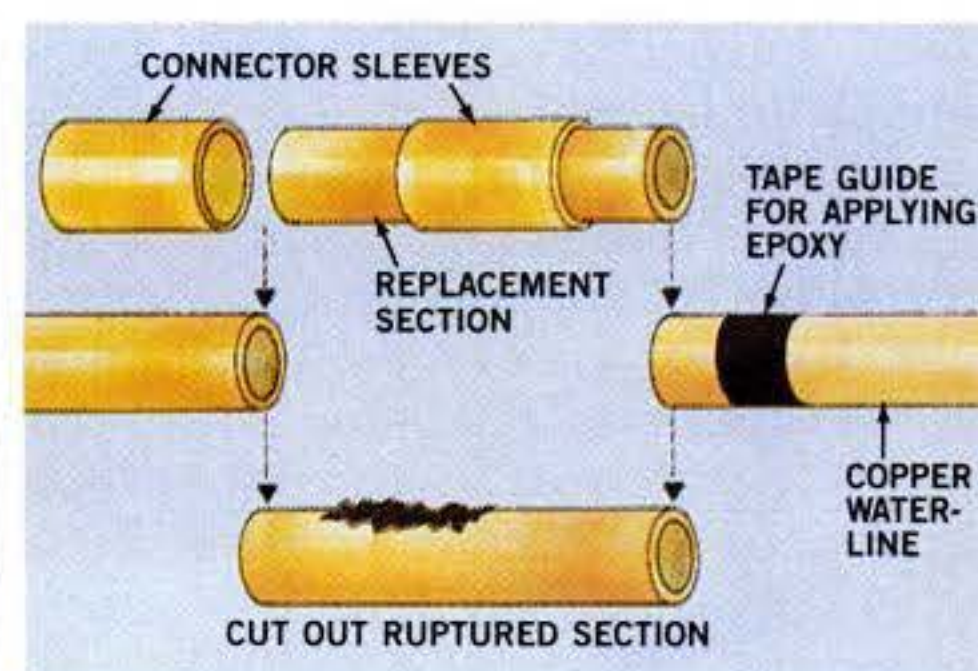
When you're closing a house (whether for a winter vacation or after winter weekends at your country place), it's always best to drain all waterlines—even if you set the thermostat to keep the indoor temperature above

freezing while you're gone. Severe cold snaps can freeze standing water and burst pipes.

But even following this advice, it's easy—if the hour is late and you're eager to be off—to drain imperfectly.

This happened last January at my weekend house. On my next trip up I restored the supply only to hear the sound of water thundering against the floorboards—and none at the sink.

Then I remembered I had tried out Copper-Bond Epoxy Adhesive for the article "Glue Up Lead-Free Water Lines" [Jan.]. So I dug out the yoked-plunger dispenser from a shop drawer and ducked under my floor to locate the damaged pipe. My lines are heat traced and wrapped with strip insulation, so I uncoiled the soggy wrap and detached the heat cable. Because the rupture was at a spot near a plastic drain line, I was grateful not to have to torch any solder joints. Instead, I hacksawed out a six-inch section, then cut a replacement nipple of the same length from identical copper tubing.



DRAWING BY HUGO SALHUANA

The only copper connectors I could find had a center ridge inside that kept them from slipping more than halfway onto the tubing. That was OK for the sleeve on the left, which I could epoxy onto the cut line in advance and let set; but the sleeve at the right had to slip all the way onto the replacement section while I aligned it with the run, as in the photo. For this I had to insert a rattail file through the sleeve and abrade the ridge flush with the inside diameter.

Then I mixed a large second batch of epoxy and liberally applied it to both sides of the exposed joint before slipping the sleeve to the right, centering it on the joint. (The wrap of electrical tape helps position it.) Actually, it's a good idea to coat the inside of the sleeve as well, to ensure a leak-proof seal and to provide lubrication.

The patch has been in service now for months. Copper-Bond Epoxy is made by Marsh Laboratories, 2437 Waverly Ave., Pittsburgh, Pa. 15218.

—Al Lees



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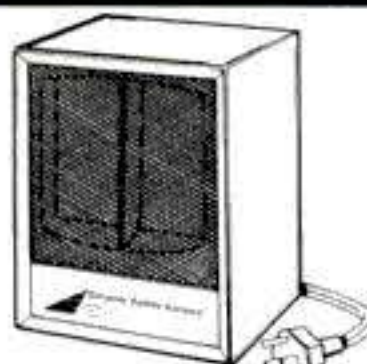
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Dirt-cheap dirt floor [Continued from page 78]

between old and new will be in a grout line.

The process of stamping Terratile is similar to that of cutting cookies out of rolled dough. The stamping tools cut so deeply through the thin slab that as the mixture dries and contracts, the tiles shrink away from each other. So after drying and shrinking, the floor actually becomes a composite of individual soil-cement tiles. And if you choose to, you can remove a few Terratiles and replace them with color-glazed ceramic tiles to add accent. You can also pour some extra Terratile on a piece of plywood or particleboard and make some tiles for detail work—perhaps a Terratile baseboard. One of the reasons I like this process so much is that it creates individual tiles, not a slab that is embossed to look like something it isn't.

Stamp as you go

To stamp the tiles we use either hard plastic stamping tools manufactured by Goldblatt Tool Co. (Kansas City, Mo.), or for smaller projects, hand-cut beveled boards. The stamping tools are best (see photos) because they provide a platform to stand on as you work. At \$50 each, however, they can be expensive if you're only pouring a small area. The major problem with using beveled board is that you must stamp each band before you pour out the next one, which in some cases forces you to wait a few minutes while a band sets up enough to stamp. With the plastic tools, as soon as a band has set sufficiently to handle your weight, you can begin stamping. Meanwhile another helper can be spreading the mix a band or two ahead.

Timing is critical. If the slab is too wet, the grout lines flow back together when the tools are pulled out. If the slab is too dry, the cutting blades on the tools will crack the edges of the tiles.

When we can, we use lines snapped into the wet slab with taut strings as guides for the stamping. Make marks two feet from the edge of the slab at both ends, draw a string tight over the marks, then lift and snap it. The line it makes in the wet slab is your guide for placing the tools.

Pouring a Terratile floor takes patience. We try to tackle no more than four hundred square feet a day, which gives us time to keep checking back on our work to make sure the tiles are flat and the grout lines clean. In fact the floor turns out best if you have enough time to re-trowel each band after it's been stamped and had a few minutes to set up. By carefully troweling across the stamped tiles, you can

knock the curls off the edges and level the transition from one tile to another.

Giving it the grout

Soil-cement takes longer to cure than concrete. Even at one inch thick, it will be three or four days before you should walk on it. To be safe, wait at least two weeks before grouting. The reason for the wait is that soil-cement continues to shrink as the water evaporates. If you grout before the tiles have finished shrinking, cracks will develop in the grout lines.

When the Terratile is dry and ready to grout, the color will be uniform and much lighter than when wet. For grouting we use 30-mesh sand and Portland cement in a four-to-one ratio, mixed wet. Start in the far corner and spread the grout mixture over the entire area with a rubber grouting float. Work the grout into the lines, then drag the float toward you at a 45-degree angle to the lines. The cleaner you get the tiles at this stage, the easier cleanup will be.

Make a pass over the area with a large wet sponge to smooth out the grout lines and clean off the tops of the tiles. Watch carefully that you don't pull grout out of the lines. Repeat the above two steps until you've completed the floor, then return to the beginning and carefully wipe off each tile one at a time with a damp sponge, keeping the water in your bucket clean. The tiles are easy to clean because the porous soil-cement sucks the water out of the thin grout so quickly, the cement doesn't stick.

Finally the finish

For outdoor use Terratile can be left unsealed. But if you want it to look its best, a few coats of wax can't be beat. Buffing with a heavy-duty floor polisher works the wax into the porous soil-cement to seal it and create a smooth finish. The tile may require two or even three coats before it's sealed. A final coat of wax will make it shine, and continual waxing will improve the look.

Terratile is just as resistant to spills and stains as a quarry tile floor. We clean ours with mild soap and water when needed, then wax and buff it. One drawback is that it can chip or dent if a heavy sharp object falls on it, but even this can be a plus: Though relatively new, already our floor has a look that resembles the patina of many years of use. **PS**

FOR MORE INFORMATION:

The author's ring-bound handbook on rammed-earth technology, first offered to POPULAR SCIENCE readers in 1982, is still available at the same price, \$11.50, from Rammed Earth Works, Blue Mountain Rd., Wilseyville CA 95257. A new videotape on the history and principles of rammed-earth building is \$25 from the same source.



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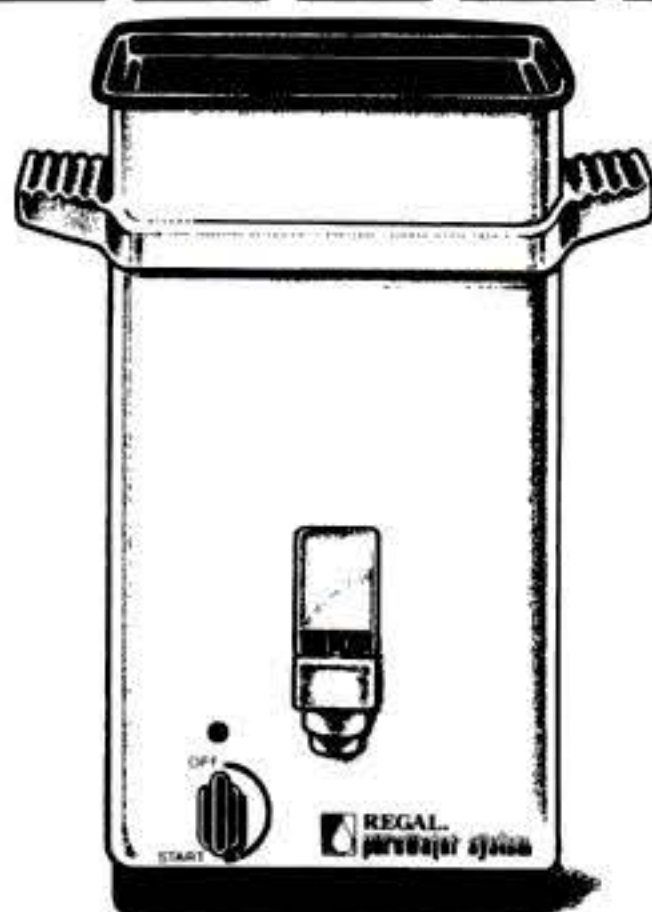
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Tornado [Continued from page 69]

which was about three to four miles deep. "We hit one good thunderstorm," Curran said to me. "But the bigger ones we were trying to intercept look as if they're going to die before they can reach us." A relieved smile creased my face. "Good practice," Curran concluded.

Chase teams have verified the accuracy of Doppler radar sightings. They've also documented the longevity of tornadoes—from a few seconds to about an hour. And they've confirmed the existence of satellite tornadoes called "suction vortices" which orbit the core of intense tornadoes and are responsible for the most violent winds.

The 1988 season is the second in which NSSL teams in vans have launched weather balloons. Radiosondes (transmitters and instruments lofted by the balloons) are used to record information about a tornado's core.

Even more useful tools are portable Doppler radars with a range of up to three to five miles (see photo). Bluestein's university-based storm-intercept team has used a portable Doppler to measure actual tornadic wind speeds. On May 25, 1987, using an ex-

perimental 40-pound unit, Bluestein's team first obtained wind-speed measurements from inside a short-lived but strong tornado churning over the north Texas plains. The team used equipment designed by Dr. Wesley Unruh at the Los Alamos National Laboratory in New Mexico. The gear consisted of two side-by-side dish antennas—one to transmit a continuous microwave beam and the other to receive the echo.

Eavesdropping on a tornado

Bluestein describes the event: "We were south of Gruver, Texas. From three miles away the radar measured tornadic winds of between 138 and 184 miles per hour." On the portable radar's receiving screen, Bluestein and his team of meteorology graduate students were able to "see" the tornado's wind speeds. They also "heard" them. The professor explains how: "Because wind speed measurements are monitored as audio, we put on earphones. In one ear you hear motion toward you; in the other, away from you. The higher the pitch, the faster the motion. While we were listening to this tornado one of the graduate students said, 'Wow, the pitch just went way up!'

That's when the tornado touched the ground."

While researchers work with portable units in the field, Dr. John T. Snow is creating simulated tornadoes in his laboratory, located at Purdue University in West Lafayette, Ind. He hopes to measure the wind speed inside a "tame" tornado sometime this year. He'll use a laser Doppler velocimeter that fires laser beams, not microwaves, at the spinning air to detect how fast the tiny particles in the air are moving.

Eventually, data from laboratory experiments and field research will be linked by computer with data from satellites, weather maps, and weather stations all over the country. This information will be used to construct the first computer models of tornadoes, similar to today's thunderstorm simulations. These models, called algorithms, describe a tornado's behavior. Simple models will take data and convert it to graphic displays that are easy for forecasters to interpret. To build more complicated models, actual weather conditions will be recorded over a long period, perhaps for many years, until a predictable pattern emerges.

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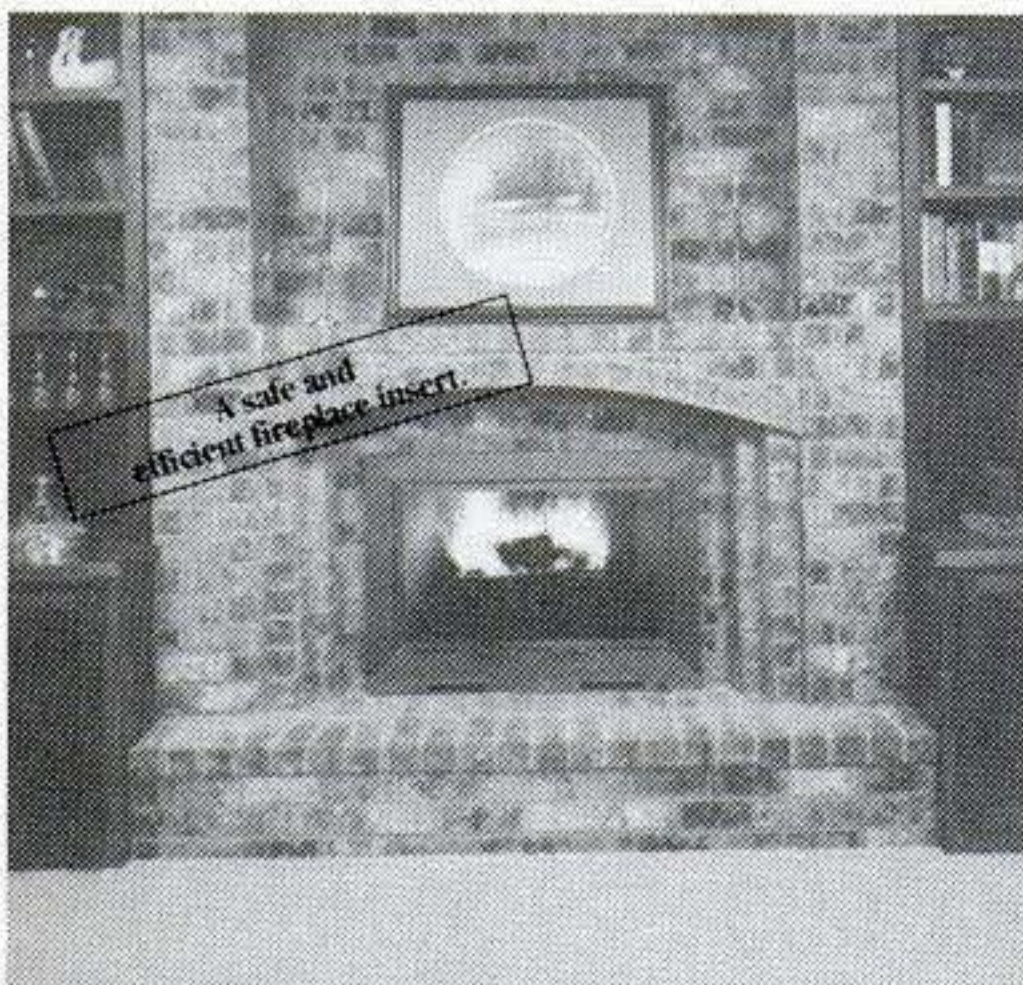
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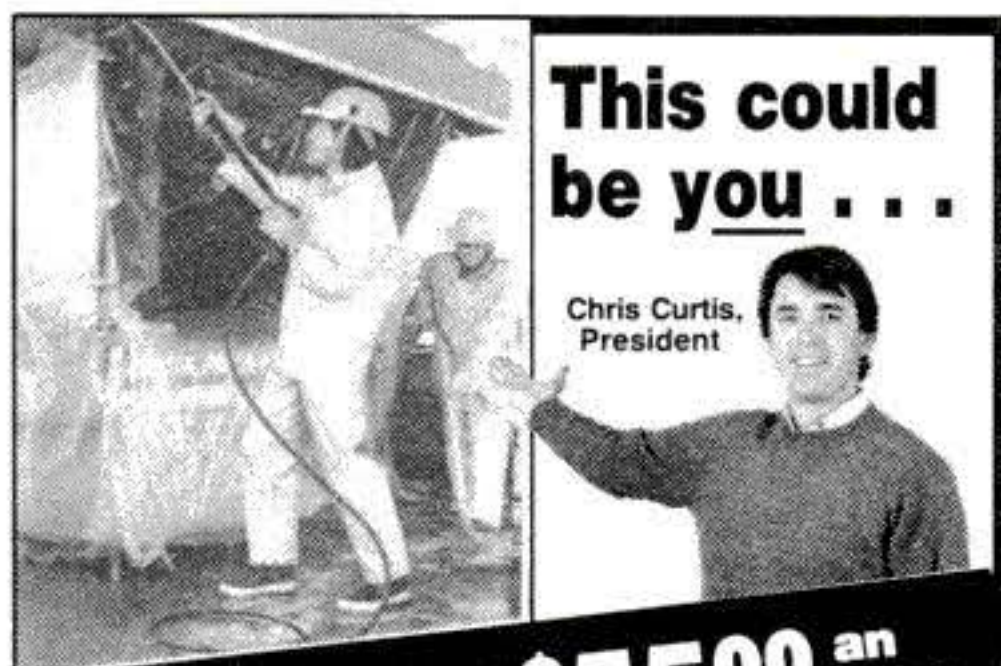
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Jump jet [Continued from page 59]

Below, the g suit hisses as it inflates to keep the blood from pooling in my legs and causing me to black out from a lack of blood in my brain. As the HUD's g meter ticks off 2 g's, 2.5 g's, 3 g's, my breathing gets progressively more labored. Perspiration really flows now . . . 3.5 g's. My diaphragm feels as if it's become part of my lower back . . . 3.8 g's. My head is very heavy. When I turn to look outside the canopy, waves of dizziness and disorientation hit me like a wall. This is much worse than any roller coaster I've ridden, for sure. I turn back to the HUD . . . 4 g's. Again I've got a death grip on the sides of the cockpit. "How are you doing?" Summoning what little pride I've got left, I manage to croak out, "Pretty good."

After what seems an eternity, Jackson straightens the plane out and the g forces drop off rapidly. "You know, this plane can pull eight g's," he notes. "Let's just fly straight for a while," is my answer. I hear a low chuckle over the intercom.

"The AV-8B's turning performance has really been improved by the LERXs—the leading-edge root extensions," says Jackson. Those small semi-circular additions to the wings where they meet the fuselage I saw when boarding create strong vortices that delay lift-killing flow separation from the upper surface of the wing.

Putting on the brakes

"Now let's say we just got jumped by an enemy fighter and he's on our back and we want to get behind him. One thing that a Harrier can do that a conventional aircraft can't is vector its nozzles forward so it brakes like a spaceship firing its retrorockets. It's a kind of *viffing* maneuver—vectoring in forward flight.

"Here's how you pull a major deceleration using the vectored thrust," Jackson continues. "Set the nozzle lever stop to the braking stop—ninety-eight degrees." With my left hand, I set the knobbed stop lever to 98 degrees. "Now, when I say so, pull the nozzle lever down to the braking stop fast, OK?" "OK." "Now!" I slam the nozzle angle lever all the way back to the braking stop with a wrench. Instantly, I'm jolted forward, the seat harness webbing digging into my shoulders. We're decelerating like a drag racer in reverse. Four seconds ago, the airspeed indicator on the HUD had read 407 knots, now it reads 300 knots.

"We just scrubbed about a hundred knots in a couple of seconds," Jackson intones while I work to recover myself. "Right now, the bogie would have streaked ahead and we'd have

him with our air-to-air missiles or our Gatling gun."

Run in and pop up

"Now we'll go down to the deck and fly fast to simulate the bomb run. You'll get a chance to see what this plane was designed for," Jackson says. "You've got to fly low to avoid the radar that guides surface-to-air missiles." The plane pitches down and accelerates rapidly as Jackson bumps the throttle up to 95 percent maximum power. Soon we're cruising 500 feet above the bay at 550 knots. Boats, buoys, and birds streak by in a blur.

As we approach the target ship, Jackson calls out a running account of the bombing maneuver. "Now we'll pop up to 1,500 feet and roll into the target." We do. "Now we're tracking the target with the ARBS, or angle-rate bombing system—a nose television-camera-based ordinance delivery system that computes the angle to the target by means of video contrast. It then computes when the bombs need to be released, figuring in angles, airspeed, type of bomb, and so forth." As I watch on the back-seat multipurpose display, the pilot selects his weapons, which are indicated by the video graphics. Jackson flies the little white plane symbol along a white pathway the ARBS indicates on the HUD.

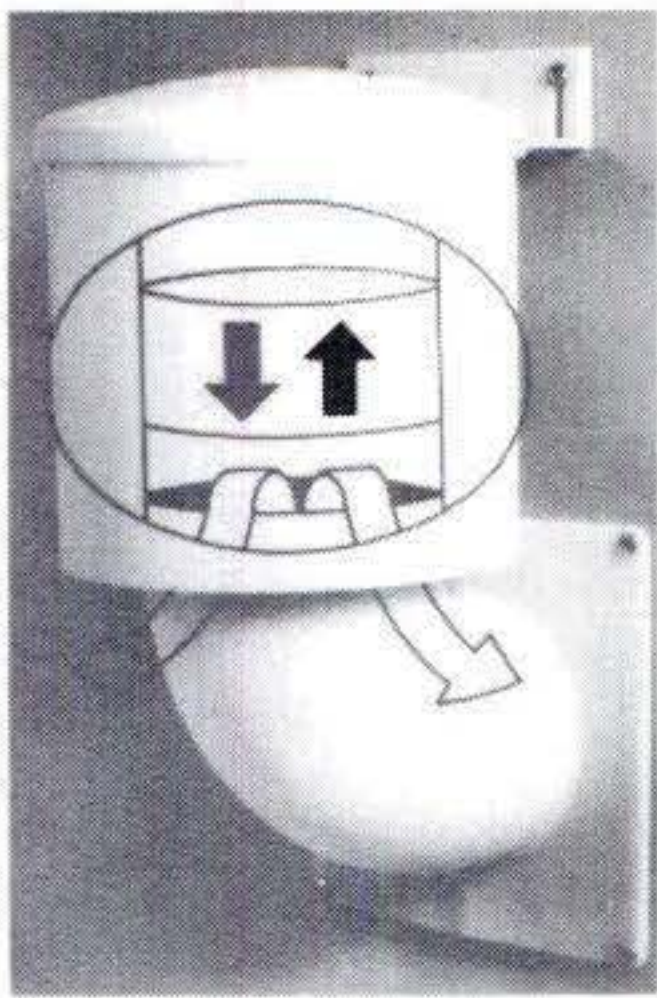
Way up ahead, I pick up the target ship—an old rust bucket anchored in the Chesapeake. The chop of the water becomes more distinct as we descend and bear down on the ship. Jackson lines up the HUD's computerized cross hairs and readies the simulated bombs. "Away," he barks, as the airplane symbol lines up with the cross hairs. "Direct hit," he tells me afterwards, interpreting the targeting display as we cruise over the target. Scratch one ship.

Magic-carpet ride

Soon we're over verdant Virginia pine forest in a Quantico training area called Davis Crossroads. "See that dirt strip down there, Steve?" I look down to see a sandy patch of ground maybe 3,000 feet long surrounded by tall conifers. "We'll make three passes at that strip as if we're going to land: the first one at 125 knots simulating the approach of a conventional airplane [nozzle setting: 30 degrees]; the second, a slow-landing approach at sixty-five knots like we would for a short field [nozzles at 88 degrees]; and third, we'll come in as if we're doing a vertical landing."

We roll in and dive toward the dirt strip for the first time. As we near the strip, it's clear that there's no way we

Continued



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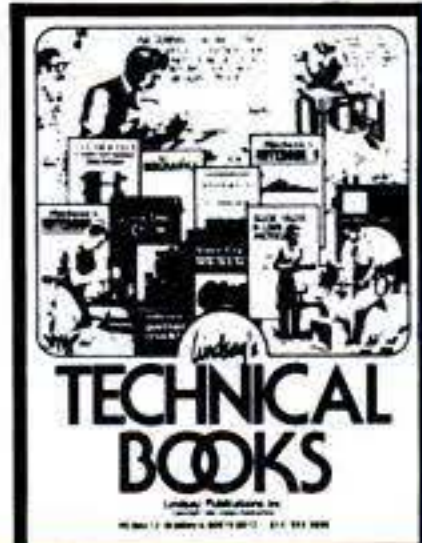
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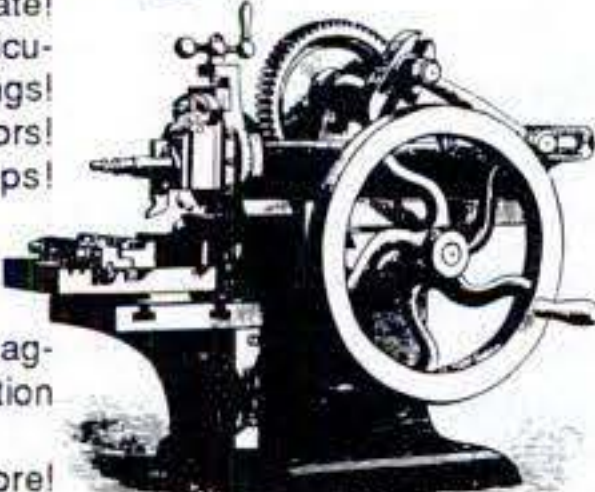
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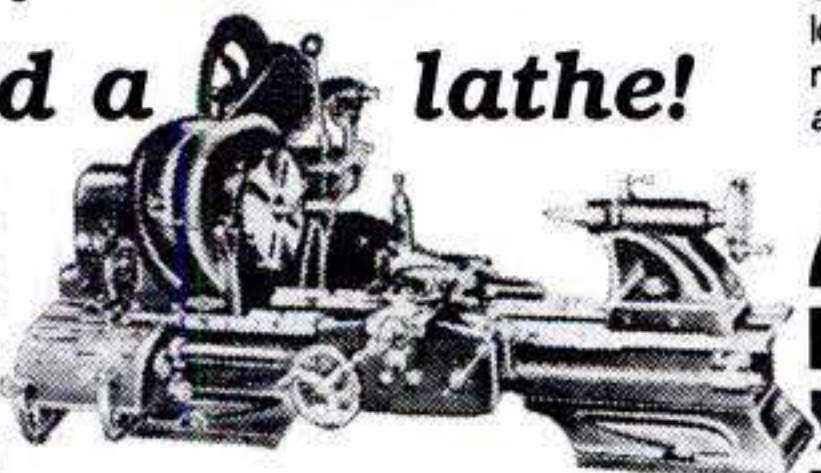
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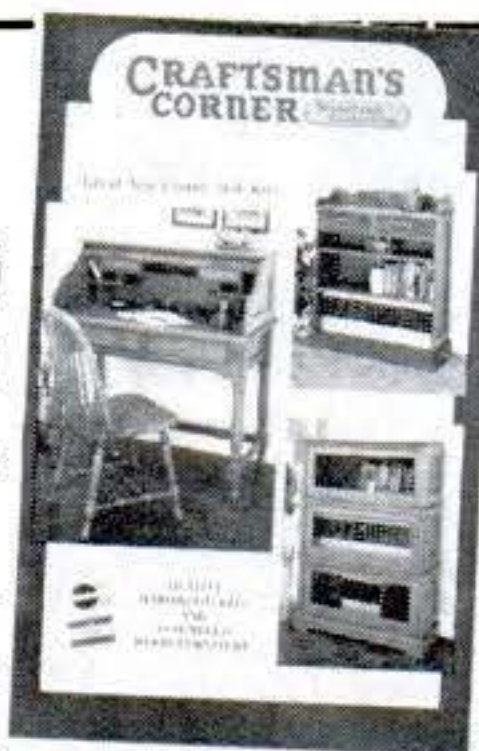
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Jump jet *Continued*

can land. We rapidly run out of runway. On the second slow-landing approach, it looks like Jackson can just barely shoe-horn the Harrier in. He climbs out again.

The third try is pure magic. Again I get a running account: "First, we have to make a transition from wing-borne to nozzle-borne flight," he explains as we drop down. The test pilot pulls the throttle to the idle position. The turbine quiets down for the first time since we took off. At 250 knots, he drops the landing gear. Then Jackson engages the STO flaps and with the lever, rotates the exhaust nozzles to 60 degrees, and juices the throttle once more. The Harrier starts decelerating. At about a half mile out, Jackson shifts the nozzles to the hover stop—82 degrees. He decelerates further using power, and at 42 knots the jump jet just quits flying. Rather, it hovers eerily like some high-tech hummingbird. Jackson checks our forward progress with a rearward movement of the control stick. "That closes the tail reaction-control valve [RCV] jet and opens the nose RCV. The other axis works the same way."

Now we hang in midair just above the 150-foot-tall trees as if we were suspended by wires. There's only a bit of swaying and buffeting, otherwise nothing but turbine noise. "It's like a magic-carpet ride!" I exclaim.

As smoothly as it arrived, the Harrier springs up and makes way for the base's airfield several miles away.

Drop it down

We sight the Quantico airfield, and Jackson brings the jump jet in over a yellow-outlined helicopter pad painted on the asphalt. This time, instead of hovering hundreds of feet in the air, he backs off the throttle and the plane begins to drop downward, supported by four pillars of exhaust. With deft movements of the stick, Jackson refines the plane's position over the pad. "I'm flying her down this time, but the attitude-hold portion of the autopilot can do a hands-off vertical landing by itself," he notes.

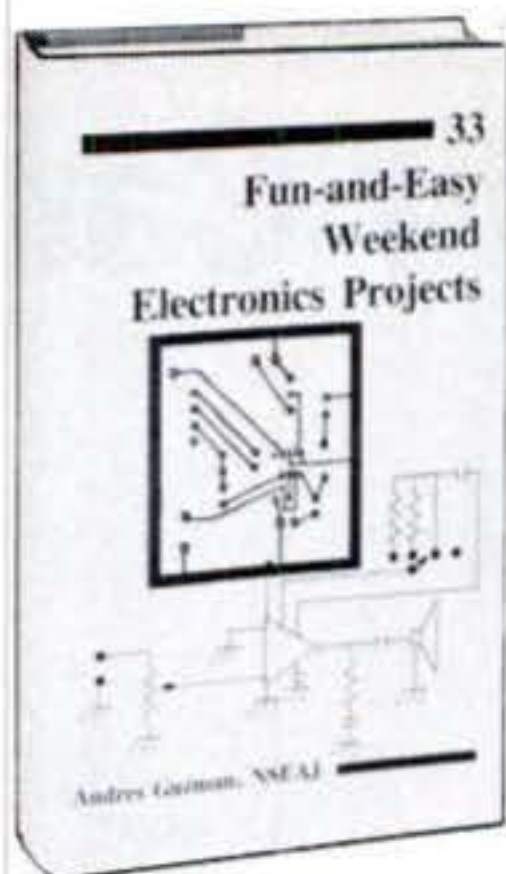
At about 25 feet, the ride gets a bit bumpy. "That's called 'cobblestoning,' because it's like rolling over cobblestones with hard wheels," explains Jackson. "It's caused by the exhaust gases reflecting back off the ground. Right now, the lift-improvement device 'box' is capturing that reflected exhaust to help keep us up. Together those air dams provide an extra 1,200 pounds of lift."

Finally, we plop down softly. Needless to say, I'm beaming. Of course, I'm also very relieved. Jump-jet flight complete.

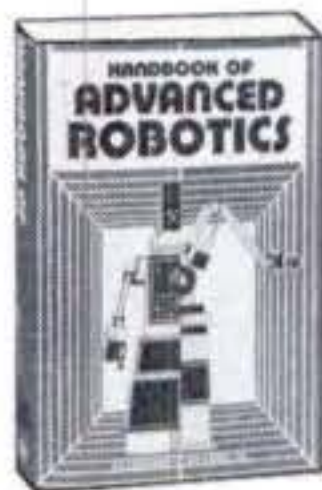
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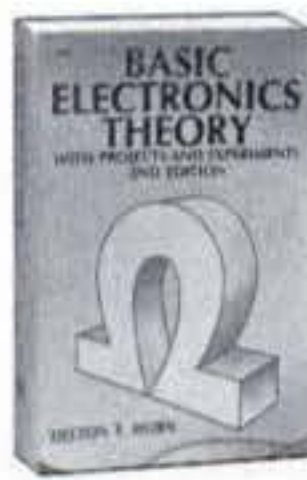
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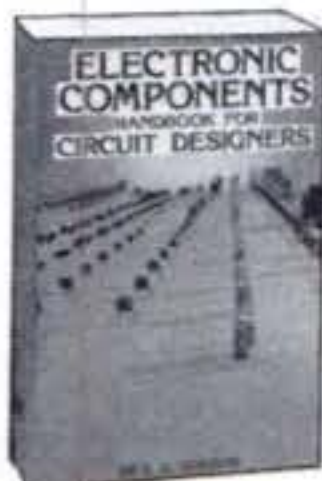
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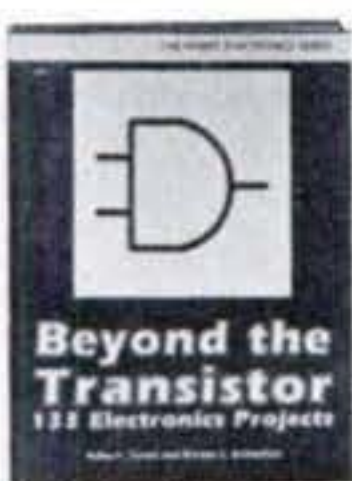
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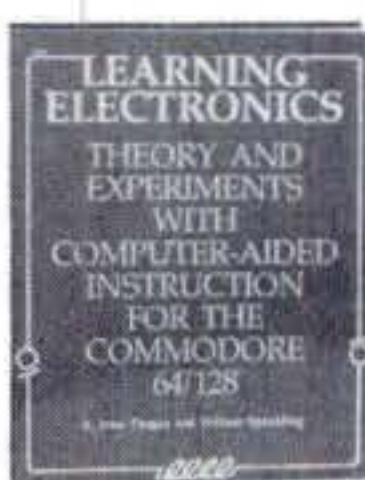
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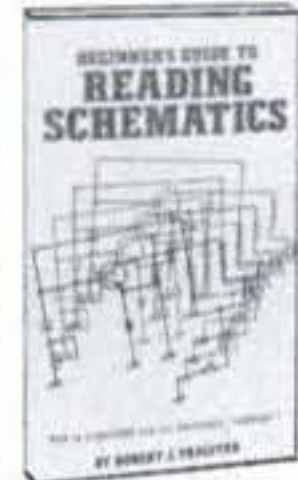
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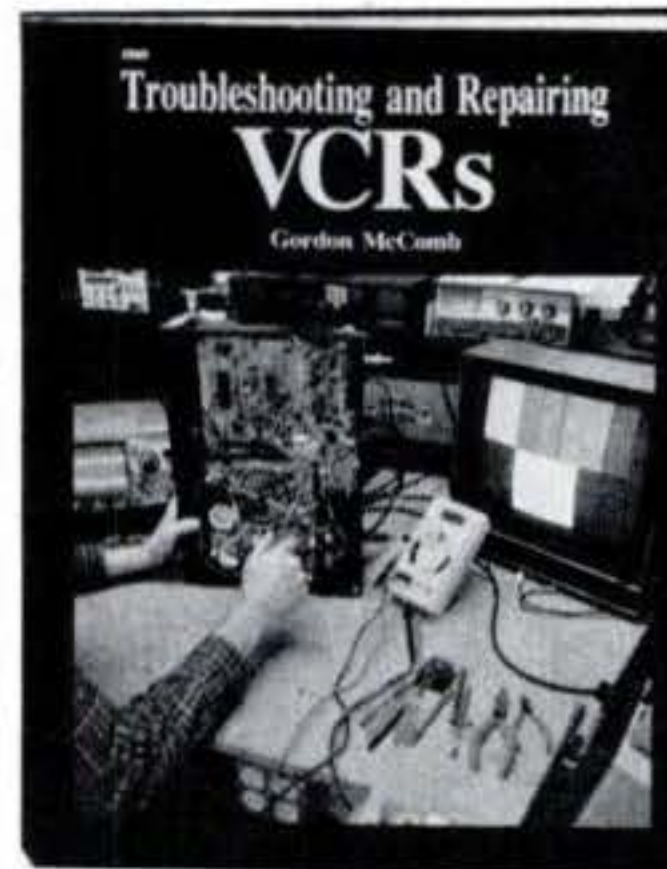
2753P \$16.95



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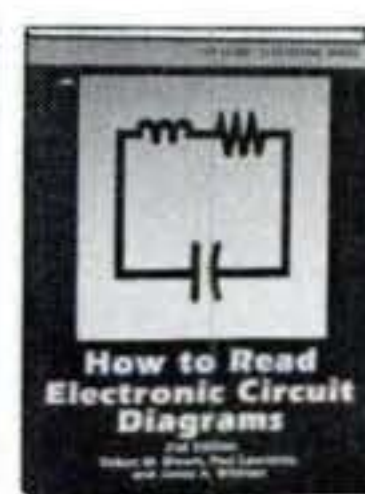
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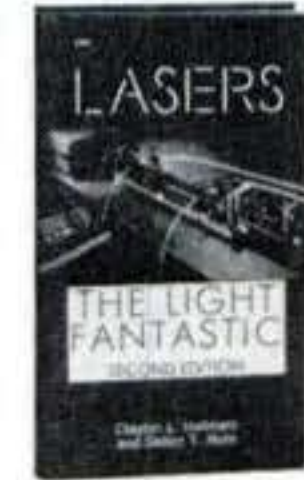
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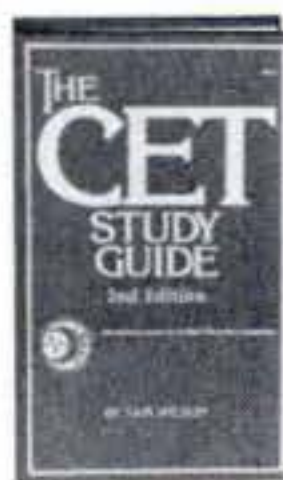


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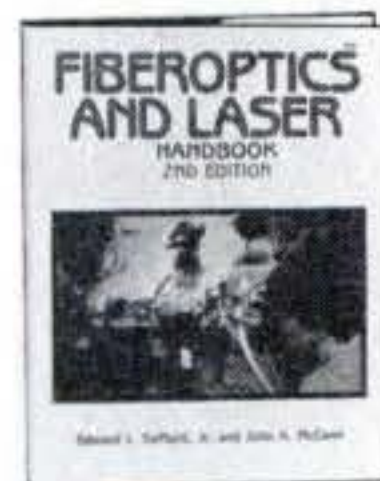
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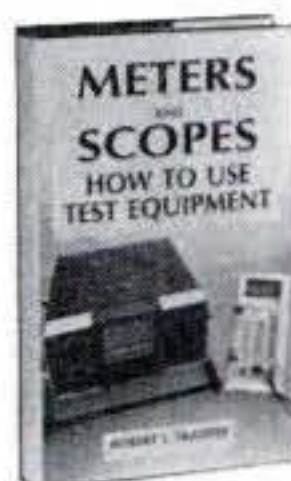
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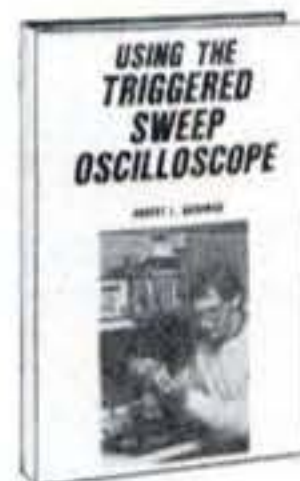
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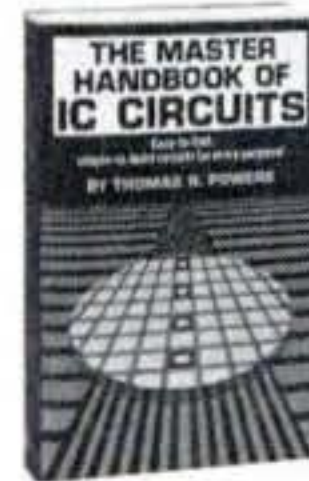
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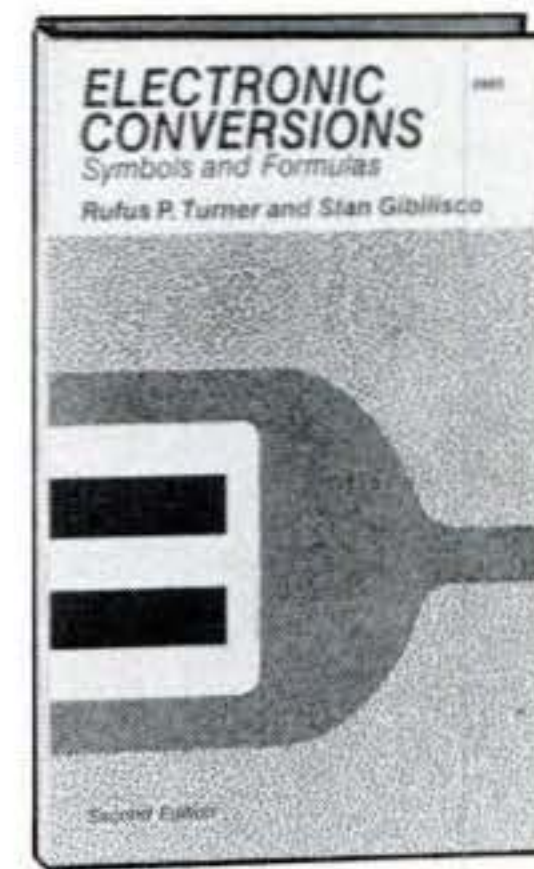
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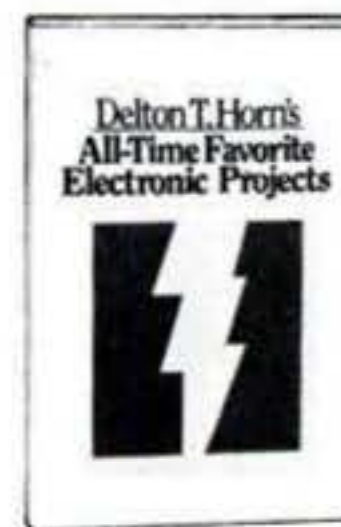
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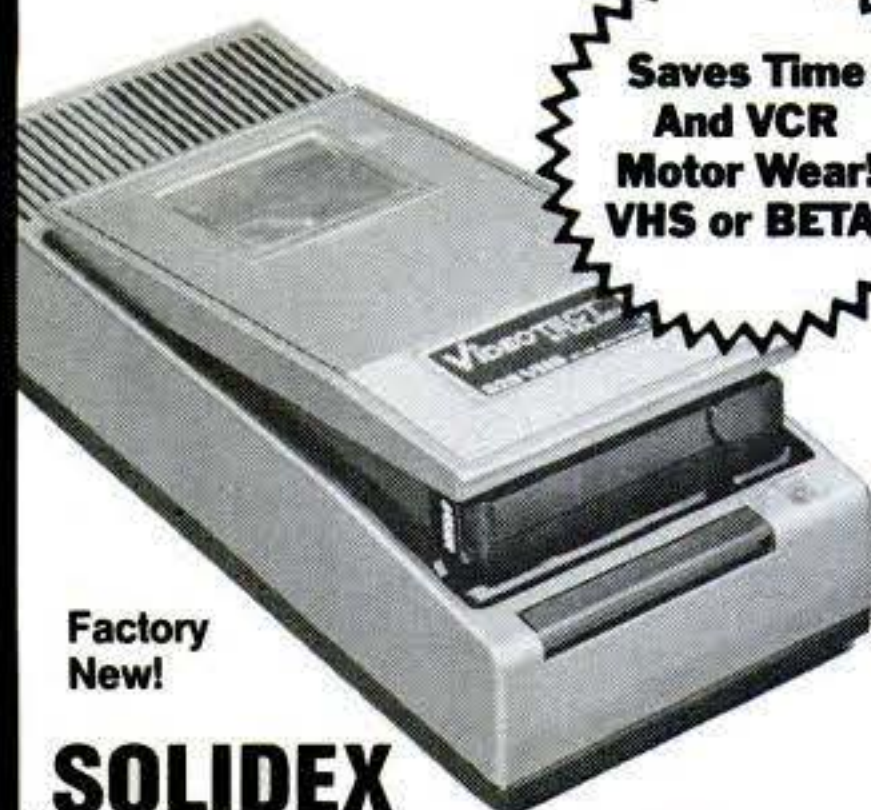
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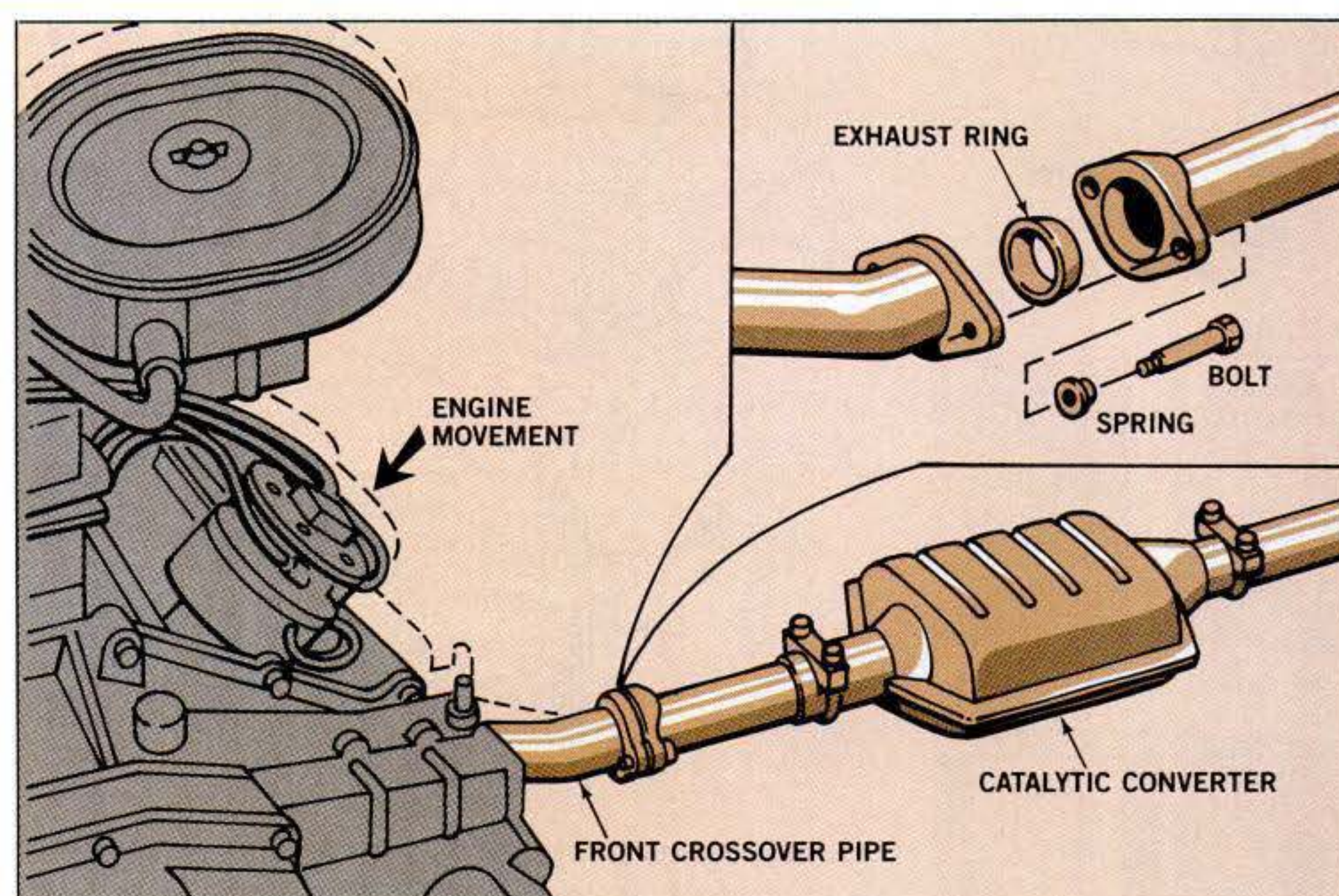
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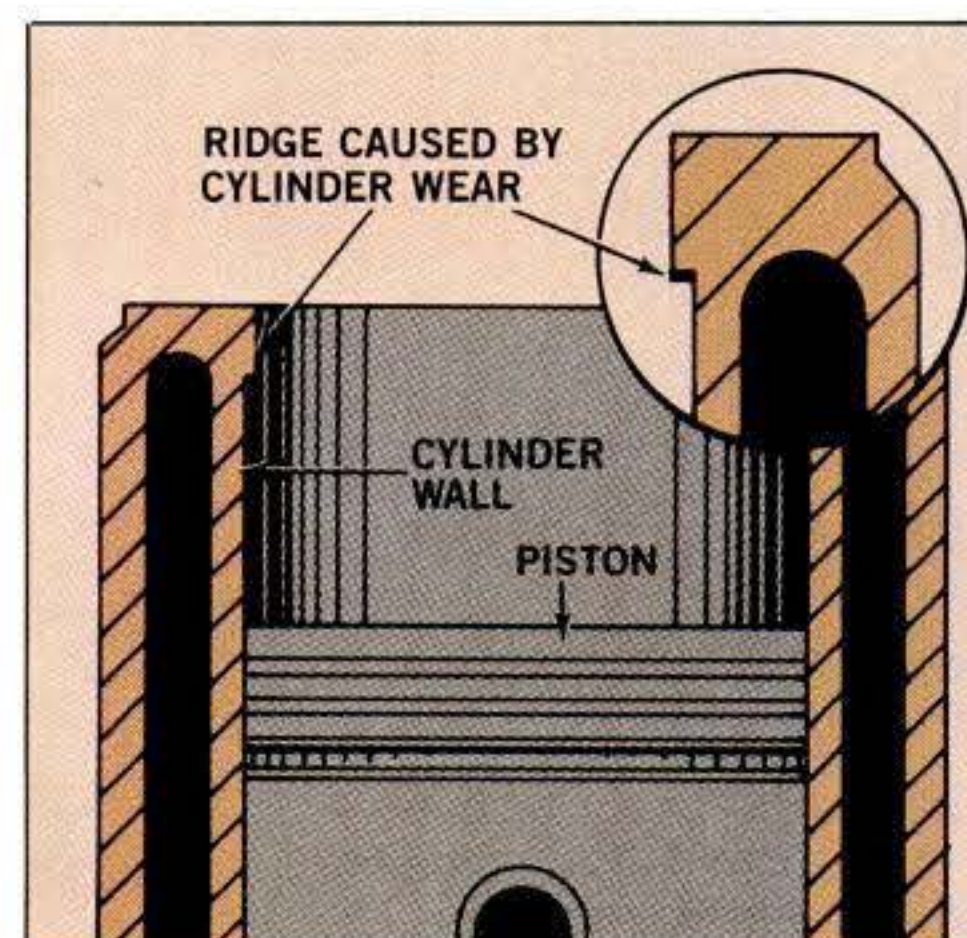
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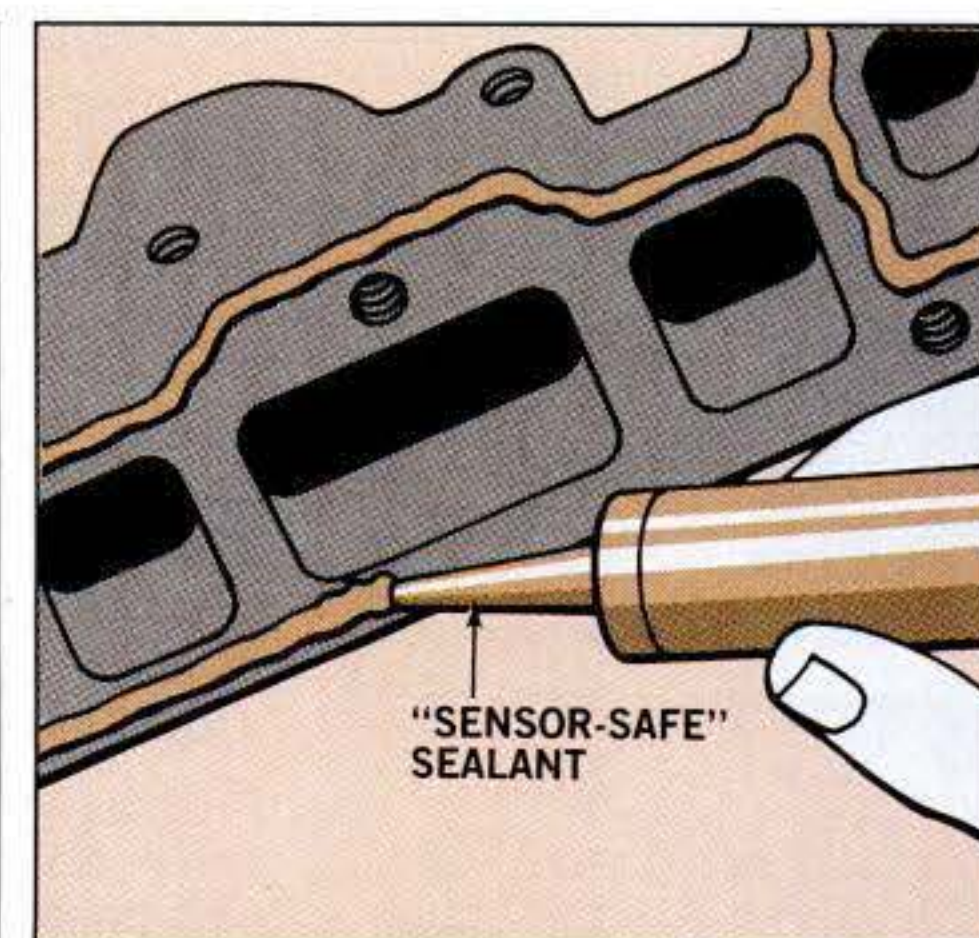
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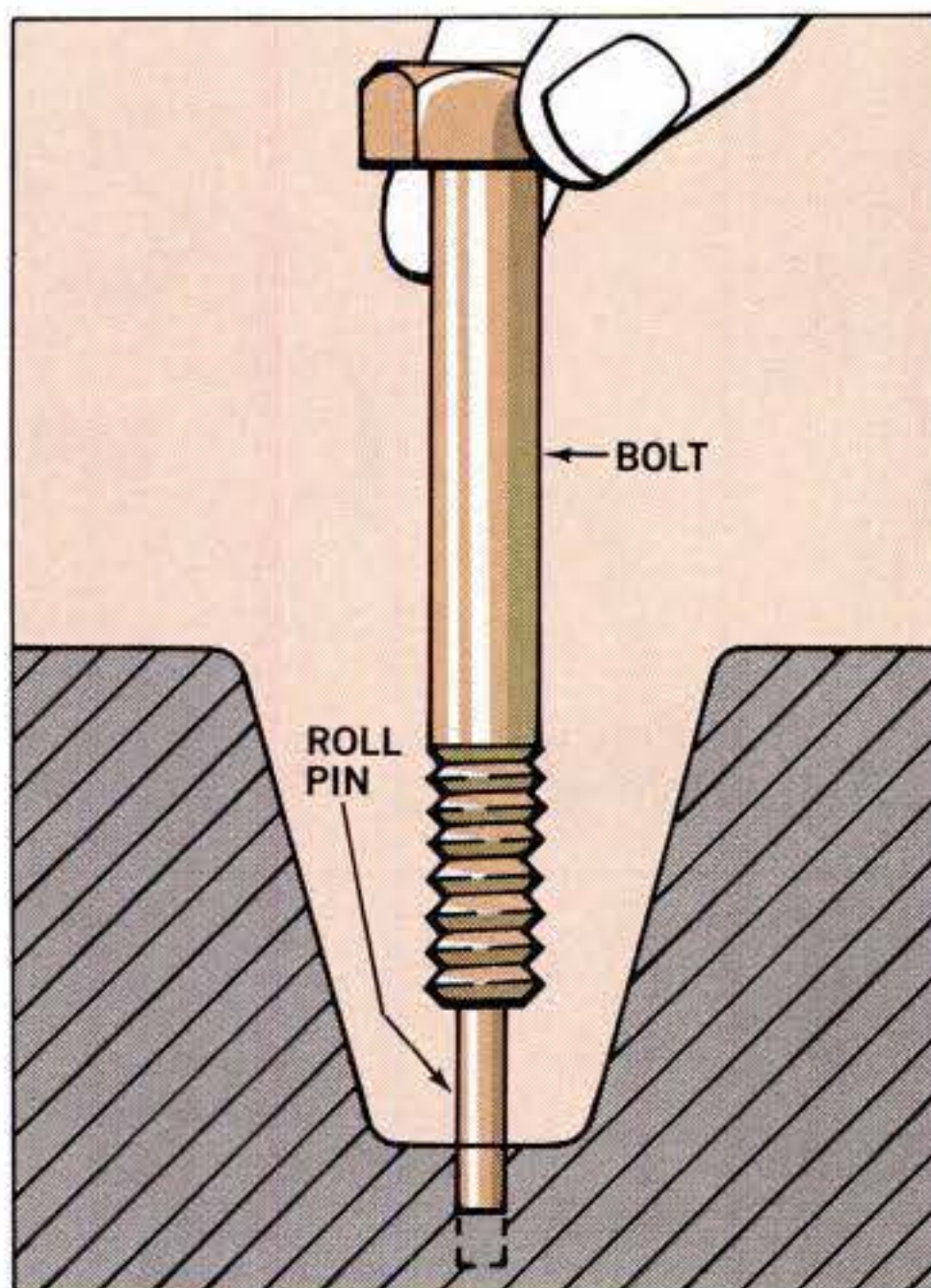
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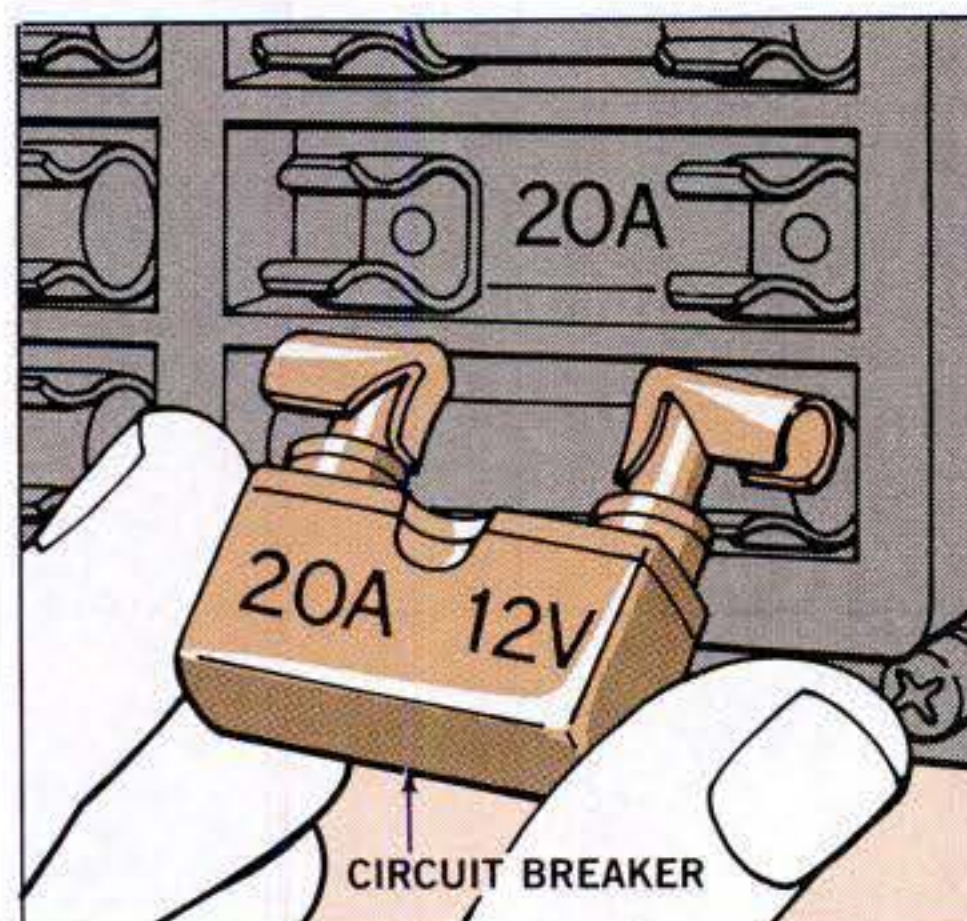
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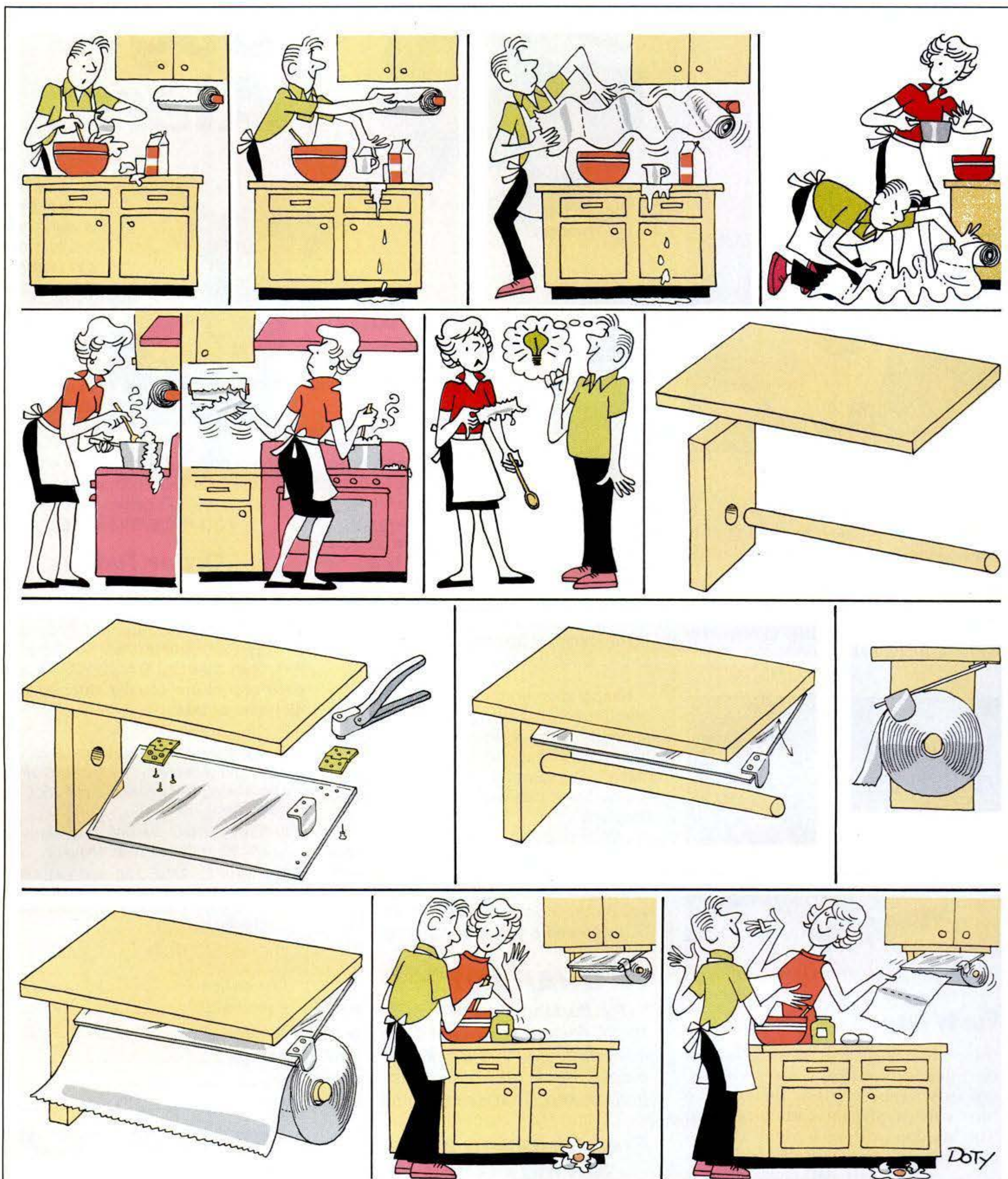


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If the same fuse keeps blowing but you can't find an electrical short anywhere, try this temporary fix. Replace the fuse with a plug-in circuit breaker. The breaker will open when the circuit overloads to protect the car's electrical system, but will close when it cools. Always replace the fuse with a circuit breaker of the same rating.

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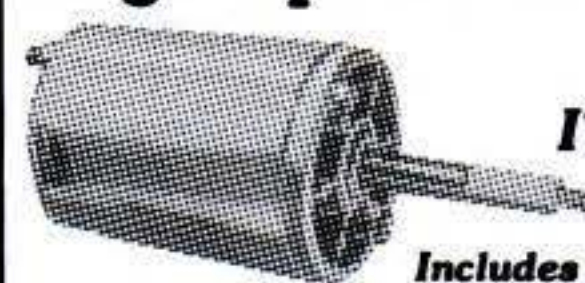
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